APPENDIX C

Shoreline Study Preliminary Alternatives and Landscape Evolution Memorandum

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memorandum

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subject **Shoreline Study Preliminary Alternatives and Landscape Evolution**

Introduction

ESA PWA is developing ecosystem restoration options for Ponds A9 to A15 and Pond A18 as part of the habitat evolution assessment for the U.S. Army Corps of Engineers (USACE) Shoreline Study. Six preliminary alternatives are being developed for habitat evolution assessment based on three Ecosystem Restoration options (No, Medium and Large Fill) combined with two Flood Risk Management alignments provided by the Shoreline Study. Professional judgment has been used to develop the candidate alternatives; no modeling has occurred at this stage.

To provide a means of comparison between the six preliminary alternatives, their habitats are being evaluated for two points in time, Time 0 (2017) and Time 50 (2067). Each alternative will be evaluated for one sea level rise curve (NRC-III curve) and three suspended sediment concentrations (including one calibrated to the Island Pond sedimentation data and two lower values). Projected pond topography in 2067 is shown in a GIS map based on existing topography and calculated accretion rates using modified Krone sedimentation equations (Krone 1985).

The first version of this memorandum, dated November 14, 2011, presented scenarios where all ponds would be restored to tidal action together beginning in 2017, 2027, and 2037. We also presented a phased scenario (West Area First) where the western most ponds (A9-11) were restored to tidal action in 2017, the east area pond (A18) was restored in 2027, and the central area ponds (A12-15) were restored in 2037. This revised memorandum presents an alternate phasing scheme (Pond A12 First) that would restore tidal action to Pond A12 in 2017, followed by the western most ponds (A9-11) in 2022, the eastern pond (A18) in 2027, and the remaining central ponds (A13-15) in 2030. The intent of this alternate Pond A12 First phasing scheme is to restore tidal action to Pond A12 as soon as possible to maximize accretion in the lowest pond in the study area.

Ecosystem Restoration Goals

The intent of the ecosystem restoration is to create ‘complete’ marshes – from subtidal through mudflats, low, mid and high marsh to transitional and upland – a true cross-section of the Bay shore. However simply providing a mix of habitats is insufficient – the marshes need to be physically and biologically ‘healthy’. To create healthy marshes requires the restoration of physical complexity - developing the natural drainage networks, natural levees, marsh pannes, and other features that are seen in ancient marshes such as those at China Camp and on the Petaluma River. These habitats also need to be connected both across shore and along shore between each other and with adjacent marshes. To create these complex and connected marshes requires larger parcels than has been the norm for restoration in the Bay, parcels which are carefully located in the landscape – ‘a few very large parcels close together are better for Bay wildlife than many small parcels farther apart’ (*The State of San Francisco Bay 2011*, p28).

Challenges

There have been paradigm shifts in the scientific recognition of the risk of abrupt climate change and accelerating sea level rise (OPC 2011) and of the risk of fine sediment availability as the erodible sediment pool is depleted (Schoellhamer 2011). After 3,000 years of relatively stable sea level and 150 years of a turbid estuary, San Francisco Bay is returning to a norm of rapid sea level rise and clear water where the landscape will be more dynamic and the bayshore will be less marsh plain and more fringing marsh. This is a dynamic landscape in which there may be downshifting of high marsh to low marsh and to mudflat over the next century; there may be landward movement of the marshes and mudflats; there may be the need to actively manage marshes more than in the past to maintain their ecosystem services.

However, the dynamic landscape reflected by these paradigm shifts is, in many ways, complementary to the ecosystem restoration goals. Wide transitional and upland areas adjacent to high marsh will allow the transgression of wetlands with rising sea level, as opposed to being squeezed against steep-sided levees. Healthy transitional and upland areas transport surface and subsurface flows of water and other materials, maintain water quality, provide macrodetritus, stabilize shorelines, store flood waters, all of which are affected by their width. Lowering outboard levees to marsh elevation, in addition to breaching, will reconnect marsh to mudflat for water, sediment, and organisms while also allowing future transgression of the outboard marshes and mudflats. The mid elevation marsh plain will play a more prominent role in attenuating waves and reducing storm surges. But a dynamic landscape implies movement and the need for space – something that is lacking on the urbanized shore of the South Bay. However the very fact that there is a juxtaposition of natural wetlands and urbanized shore creates opportunities for multi-objective restoration projects which have value for flood risk management, levee stability and stormwater channel maintenance.

Alternatives

Three Ecosystem Restoration (ER) options for Ponds A9 to A15 and Pond A18 have been developed. It is assumed that once tidal flows have been restored by breaching the outboard levees, natural sedimentation will allow the evolution of a marsh plain in the ponds. The ER options have some common features, such as number and location of levee breaches. Measures in the marshplain such as pilot channels, starter channels, side cast natural levees and ditch blocks will be used to accelerate the evolution of the ponds and to enhance the habitat. The ER options differ mainly in the amount of fill which is used to create upland and transitional habitat adjacent to the inboard levees along Pond A12 and A13 and along Pond A18: the ER options are named No, Medium and Large Fill. Using fill to create long transitional slopes provides large areas of upland habitat that has been missing from the Bay, attenuates waves and reduces run-up, and increases resiliency to sea level rise. Increasing amounts of fill also increase the cost of the project and increase the demand for dredged (or other fill) material. The ER options therefore bookend the project in terms of cost, volume of fill, habitat quality, flood risk management benefits, and resiliency to sea level rise.

The Flood Risk Management options for Ponds A9 to A15 and Pond A18 are described in the Draft FRM Option Development Memorandum (HDR 2011). For Ponds A9 to A15 the FRM options follow two alignments: either along existing levees bordering Pond A12 and A13 (FRM options 1A, 1B, 1C, 1D and 2) or along existing levee bordering pond A12, and then west along the existing railroad line to Grand Boulevard (FRM options 3 and 4). For Pond A18 the FRM options also follow two alignments: either along existing levees bordering Pond A18 (FRM options 2 and 4) or along a new alignment cutting across Pond A18 (FRM options 1A, 1B, 1C, 1D, and 3). FRM options along Pond A16 and in New Chicago Marsh will not impact the ER options for Ponds A9 to A15 and Pond A18 and so are not considered further in this memo.

The six preliminary alternatives are a combination of the FRM and ER options as shown in table 1 below. Pond A9-A15 and Pond A18 are physically separated and considered to be independent of each other; any of the alternatives chosen for Pond A9-A15 could be matched with any of the alternatives for Pond A18. The benefits of applying the other ER measures, such as starter channels and ditch blocks, are being studied as part of the Island Ponds and Pond A6 monitoring which are Phase 1 actions of the SBSP Project. The inclusion of such measures in the preliminary alternatives should be based upon information from this monitoring.

Figures 1 to 3 show the fill footprint for Preliminary Alternatives 1 to 3, where the FRM alignment follows the existing levee, together with the existing topography. Topographic shading reflects the initial habitat types that would be expected based on tidal inundation regimes if the Ponds were all breached in 2017. The levees, fill footprint and other measures are described in the next section.

Table 1: Preliminary alternatives for Ponds A9-A15 and Pond A18

Preliminary Alternative	ER option	Other ER measures	FRM alignment Pond A12 and A13	FRM alignment Pond A18
1	No Fill	Outboard levee breaches, pilot channels, and internal berm breaches	Existing levee	Existing levee
2	Medium Fill	Outboard levee breaches, pilot channels, outboard levee lowering, ditch blocks, internal berm breaches, internal berm lowering, and starter channels with side cast natural berms	Existing levee	Existing levee
3	Large Fill	Outboard levee breaches, pilot channels, outboard levee lowering, ditch blocks, internal berm breaches, internal berm lowering, and starter channels with side cast natural berms	Existing levee	Existing levee
4	No Fill	Outboard levee breaches, pilot channels, and internal berm breaches	Existing levee along Pond A12, and then along the existing railroad line	New alignment cutting across Pond A18
5	Medium Fill	Outboard levee breaches, pilot channels, outboard levee lowering, ditch blocks, internal berm breaches, internal berm lowering, and starter channels with side cast natural berms	Existing levee along Pond A12, and along the existing railroad line	New alignment cutting across Pond A18
6	Large Fill	Outboard levee breaches, pilot channels, outboard levee lowering, ditch blocks, internal berm breaches, internal berm lowering, and starter channels with side cast natural berms	Existing levee along Pond A12, and then along the existing railroad line	New alignment cutting across Pond A18

Measures

Flood Risk Management Levees

To estimate the fill footprint an approximation of levee crest heights is required. PWA (2006) documents concept level designs for levees in the Alviso pond complex classified into a number of categories the following of which are relevant to the present study:

- New levee constructed on existing pond-bottom elevations
- Upgraded levee constructed on existing perimeter levees (typically the “inboard” levee located on the landward side of the ponds)

In addition, each typical flood control levee category was separated into three different exposure levels:

- Exposed levee landward of tidal marsh
- Exposed levee landward of an upland-transition area
- Reduced exposure levee landward of a managed-pond area

Table 2 shows conceptual design levee crest elevations from the SBSP Flood Analysis Report (PWA 2006). The conceptual design elevations are based on 100-year “total water levels” with an additional 1 ft allowance for freeboard. The total water level is defined as the combination of a high bay-water level and wind-wave runup. For this preliminary analysis, the joint occurrence of a 100-year bay-water level and a 10-year wind wave event was used to estimate the total water levels and required levee crest elevations for each exposure level. Levees landward of tidal marsh and upland-transition areas are assumed to be more exposed than levees landward of managed ponds. Long and short wave modeling by the USACE and Delta Modeling Associates will provide better estimates of total water levels at the levees following breaching and in 2067 and levee design crest elevations should be updated.

Table 2 Alviso Levee Design Crest Elevation from PWA Flood Analysis Report (2006)

Levee Exposure Category	Levee Design Crest Elevation (ft, NAVD88)
With Outboard Marsh / Upland Transition	16.5
With Outboard Managed Ponds	15.5

New and upgraded levee cross-sections are assumed to have inboard and outboard slope of 3:1 (H:V) and a crest width of 20 ft. To prevent levee erosion, new and upgraded levees that are fronted with either tidal marsh or managed ponds are assumed to be armored with rock. The armoring design used in the cost estimate is a rock revetment to be placed between the top elevation of the stability berm or upland transition area and the crest of the levee.

Elevations for existing perimeter levees for Alviso and Ravenswood are from Moffatt & Nichol (2005). Table 3 summarizes the elevation data used in estimating fill volumes for design levee cross-sections.

Table 3 Typical Existing Elevations in Alviso; crest elevations from Moffatt & Nichol (2005)

Levee Exposure Category	Elevation (ft, NAVD88)
Average Pond A12 Elevation	-0.5
Average Pond A18 Elevation	0.5
Internal Managed-Pond Berm Crests	6
Existing Perimeter Levee Crests	9

Stability berms may be required to prevent subgrade failure potentially resulting from the rapid placement of between 10 and 20 feet of soil. If required, these berms would be needed on both sides of a flood control levee that is exposed to either a tidal-marsh area or a managed pond. For a flood control levee that is exposed to an upland-transition area, only the landward side of the levee will need a stability berm. Stability berms are assumed to have crest elevations approximately 2 feet above mean higher high water (MHHW). The widths of the stability berms would vary depending on the type of levee and will have assumed side slopes of 3:1 (H:V). Due to differences in fill thickness and subgrade strength, the width of the stability berms for a new levee, an upgraded internal managed-pond berm and an upgraded existing perimeter levee would be 50 ft, 40 ft and 30 ft, respectively. The locations of drainage and borrow ditches will need to be considered and may alter the alignment. Alternative methods may be available which could be less expensive. These include soil reinforcement with geotextile fabric, stone column or foundation over-excavation, or replacement with stronger soil.

Initial fill volumes will likely include an “over-build” to compensate for the initial subsidence and an allowance should be made for placing additional earth (or other action such as a flood wall) as the levees subside. Initial subsidence is anticipated to be greatest for new levees constructed on existing pond bottoms.

Transitional-Upland Slopes

Three different cross-sectional designs for the transitional-upland areas adjacent to the levees are used, which correspond to the three ER options of No, Medium and Large Fill, and described in Table 4. For each design, the top of the transitional-upland area was assumed to be the same as the proposed levee crest elevations from Table 2 and the bottom of the transitional-upland area was assumed to be about 2 feet below MHHW within the lower range of cordgrass grass dominated marsh. Below the flat transition slope, the berm would slope down to the respective average pond-bottom elevations as shown in Table 3 at a steeper 3:1 to 5:1 (H:V) slope.

Table 4 Transitional-Upland Slope Design

ER Option	Design
No Fill	3:1 (H:V) front slope of the levee and stability berms (if required) form the transitional zone.
Medium Fill	30:1 (H:V) slope for the transitional zone. The zone begins at the approximate upgraded flood-control levee crest and maintains a 30:1 slope to the pond-bed elevation. It is assumed that the upper slope of the transitional zone will need planting or hydro-seeding.
Large Fill	100:1 (H:V) slope for the transitional zone. The zone begins at the approximate upgraded flood-control levee crest and maintains a 100:1 slope to the pond-bed elevation. It is assumed that the upper slope of the transitional zone will need planting or hydro-seeding.

The 30:1 and 100:1 (H:V) slopes in the Medium and Large Fill options represent idealized slopes. During final design and construction, the slopes would include some variation both in planform to create a more natural shoreline and along the slope to create benches and shallow depressions to form pannes at a variety of elevations. The intent is to work within the overall idealized slope to create an upland transitional zone with some complexity.

To reduce the initial fill requirements it may be possible to construct the transitional-upland slopes of the Medium Fill and Large Fill options in stages. An initial, smaller, berm would be built at the outboard edge of the transitional-upland zone, followed by breaching the ponds to tidal action, then filling behind it over time as material becomes available to bring the transition areas to final grade. An alternative may be to maintain a 3:1 slope to a horizontal bench located one-foot above MHHW. The levee bench could receive fine grading to create backshore pans and a 30:1 (or 100:1) slope will continue downward from the bench to about 2 feet below MHHW within the lower range of cordgrass colonization elevations. Additional fill would be placed on the bench as required to maintain its position in the tidal frame with sea level rise.

Outboard Levee Breaches

Outboard levee breaches are excavations through the perimeter levees that open the site to tidal inundation from the adjacent tidal sloughs. Breaches through the outboard levee and pilot channels through the outboard marsh will be excavated at the locations of the major remnant historic tidal channels (Figure 4). These locations would be the same for all the Preliminary Alternatives.

The levee breaches are sized using empirical relationships between tidal channel dimensions and marsh drainage area (hydraulic geometry relationships). Hydraulic geometry relationships from Williams et al (2002) are based on data from tidal channels in mature natural marshes located throughout the San Francisco Bay. A subset of the Williams et al (2002) data from South Bay marshes, including Laumeister, Newark Slough, and Ravenswood Slough, was used to develop hydraulic geometry relationships for the South Bay.

The hydraulic geometry relationships provide expected channel dimensions once a pond has developed into a mature marsh. The breaches were sized to long-term equilibrium dimensions to balance excavation costs, scour potential, and tidal drainage (see section below). This approach is consistent with the Design Guidelines for Tidal Wetland Restoration in San Francisco Bay (PWA 2004). These dimensions are adjusted to give a trapezoidal breach cross section with side slopes (H:V) of approximately 4:1 to 5:1 and a minimum bottom width of approximately 10 ft. On the inboard side of the levee, the breach excavation will extend to the levee toe

The breaches are expected to be undersized compared to restored tidal flows due to the larger tidal prism of the subsided ponds. The large tidal flows are expected to scour and enlarge the breaches until equilibrium between the tidal prism and channel dimensions is reached. The tidal prism will decrease as the pond fills in due to sedimentation and vegetation establishment.

Undersized breaches may initially constrict tidal flows to the restoration site and cause water to “back-up” in the site on the ebb tide, delaying drainage and increasing the low water level in the site. The pilot channel connecting the levee breach and the adjacent slough through the outboard marsh (pilot channel) may limit tidal drainage in a similar manner. Over time, tidal flows are expected to scour undersized levee breaches and pilot channels, thus improving tidal drainage.

Outboard Levee Breach Sizing

The historic channels layer from SFEI was examined in GIS to analyze historic watersheds on the site (Figure 4). The area of each restored tidal watershed was calculated in GIS and used to find long-term channel equilibrium dimensions for that watershed using Williams *et al*, 2002 (). The order of each channel was determined from Williams *et al*, 1995 (). These dimensions can be applied to the historic channel network shown in Figure 4.

Table 5. Long-Term Equilibrium Channel Dimensions

Watersheds	Area [ac]	Breach Depth [ft]	Breach Top Width [ft]	Breach Cross-Sectional Area [ft^2]	Channel Order
Pond A9	454	16.1	188	1303	6
Pond A10	228	13.5	138	820	5
Pond A11	246	13.8	143	864	5
Pond A12	265	14.0	147	907	5
Ponds A13-15	914	19.1	257	2081	6
North A18	116	11.4	101	521	5
Central A18	221	13.4	136	805	5
Southwest A18	258	13.9	146	892	5
East A18	255	13.9	145	886	5

Pilot Channels

Wide mudflats outboard of breaches may limit tidal drainage; however, the pond breaches drain to deep tidal sloughs across relatively narrow mudflat channel banks. Pilot channels will be excavated through the outboard marsh to connect each outboard levee breach to the adjacent tidal slough. The ponds will be breached at the location of historic marsh channels and so the pilot channels would also follow the historic channels (Figure 4). These locations would be the same for all the Preliminary Alternatives.

The Design Guidelines (PWA 2004) recommend excavating breaches and pilot channels to long-term equilibrium dimensions to allow for adequate tidal exchange to quickly erode breaches and improve tidal drainage. Pilot channels will be excavated to the long-term equilibrium channel depth and 60 to 80% of the long-term channel width (i.e., narrower than the breach width at MHHW) (see above). The pilot channel side slopes will be approximately 3:1. The pilot channels are somewhat undersized to reduce the amount of excavation and are expected to scour and enlarge. Marsh vegetation will be excavated down to the root zone over the long-term equilibrium width to reduce the resistance to pilot channel bank erosion.

Tidal drainage for the pond restoration is likely to be adequate in the long-term, but may be restricted within the first few years after restoration. An assessment of Island Ponds monitoring data (PWA 2007) indicates that after the under-sized Island Pond breaches scoured to long-term equilibrium widths, the breaches provided adequate tidal drainage. These monitoring data suggest that breaches sized to long-term equilibrium dimensions for ponds with marshplain elevations similar to the Island Ponds can be expected to provide adequate tidal drainage. The elevation of the ponds is on average 3 feet lower than the Island Ponds and will initially have a larger restored tidal prism, which will tend to slow drainage at low tides. However, the number of breaches per acre of restored marsh will be greater than the Island Ponds, which will tend to improve drainage. If the pilot channels do not scour and enlarge as expected, excavation could be pursued as part of adaptive management.

Outboard Levee Lowering

Levee lowering would occur in the Medium and Large Fill Preliminary Alternatives. The majority of the outboard levee will be lowered by excavation to MHHW to create pickleweed marsh habitat, restore hydraulic and habitat connectivity between the sloughs and the marshplain, and provide material for ditch block construction. Portions of the outboard levees will not be lowered to limit wave action and to provide initial high tide refugia. The bayfront levee between Pond A9, and Coyote Creek is expected to limit wave action in Pond A9 until the bayfront levee completely erodes.

Borrow Ditch Blocks

Ditch blocks inhibit flow though the existing borrow ditches to promote scour and flow through the remnant historic channels. The desired elevation of the top of the ditch blocks is MHHW; at this elevation the ditch blocks are expected to provide pickleweed habitat. The initial fill elevation needed to achieve this elevation and account for settlement will be determined during final design. Material excavated from the levee breaches and levee lowering will be used to construct ditch blocks. To reduce the potential for fish stranding, the ditch blocks will be located such that the borrow ditch on both sides of the block connects directly to a breach.

Internal Berm Breaches

The internal berms within the ponds will be breached in several locations to reconnect remnant historic channels and restore the hydraulic connection across the site (figure 4). Breaches will be sized in a similar manner to the breaches in the outboard levee. The breach excavations will extend beyond the levee toe into either the internal borrow ditch or the remnant historic channel. The existing internal berm between Ponds A9 and A14 does cut across the historical watershed (Figure 4). It is suggested that this berm is realigned further into Pond A14 so that the tidal prism will be sufficient to maintain the channels in Pond A9. The benefits and costs of adjusting the internal berm alignment need to be addressed at a later stage in the design.

Internal Berm Lowering

Internal berms within the ponds would serve as wave-break berms to limit wave action, enhance sedimentation, and create vegetated marsh habitat (on the berm crests) in the short term while the ponds develop from mudflat to vegetated marsh. The existing low internal berms separating the ponds would be lowered by excavation to MHHW to create pickleweed marsh habitat and act as a wave-break berms. This is the concept used in the adjacent Pond A6 and monitoring of sedimentation rates following restoration will test its effectiveness. Construction of additional wave-break berms is not included at this point because the benefits to the pond restoration may be small relative to the cost of construction. Short wave modeling by USACE may indicate the need for wave-break berms.

The extent and location of internal berm lowering would be determined during project design to match project construction to funding availability.

Starter Channels with Side Cast Berms

Natural levees adjacent to tidal channels in historic marshes support pickleweed and marsh gumplant which serve as critical high tide refugia for Salt Marsh Harvest Mouse and California Clapper Rail. Excavation of the shallow remnant historic tidal channels within the ponds would provide material to create side cast berms adjacent to the channels to emulate natural levee features seen adjacent to channels in historic marshes. These low berms would create topographic complexity within the otherwise plainer intertidal mudflat.

In addition, excavating the shallow remnant historic tidal channels within the pond would re-create tidal channel habitat and improve tidal drainage more rapidly following restoration. Tidal drainage is affected by the density, complexity, and form of the channel network. As water drains off the marshplain, flows are conveyed through tidal channels within the site. Silted-in portions of the remnant historic tidal channels (Figure 4) may be too shallow to efficiently convey tidal flows, causing more flow over the marshplain. Shallow flow and friction over the marshplain may delay low tide drainage. Tidal drainage is expected to improve as remnant channels scour in response to tidal flows. Ponds with a gypsum layer on the pond bed may also require excavation of channels to convey tidal exchange – the only ponds in the Alviso complex known to have gypsum layers are the Island Ponds.

Using a similar hydraulic geometry analysis as for pilot channels, starter channels could be excavated that are sized to the long-term equilibrium channel depth and 60 to 80% of the long-term channel width. The ultimate location and extent of starter channel excavation to create side cast berms would be determined during final design to balance the habitat benefits with project funding. For instance, in Ponds A15 and A13, existing internal berms are located adjacent to the large tidal channel through those ponds, so the need for excavation to create side cast berms would be a lower priority within those ponds. By comparison, within Pond A18 there are no internal berms within a large 850 acre pond, and starter channel excavation to create side cast berms would be a much higher priority in Pond A18 because these berms would serve a number of critical functions – as wave-break berms to enhance sedimentation, to provide topographic complexity to support vegetation colonization, and to provide high tide refugia for critical special status species.

Experience in the Island Ponds indicated that material sidecast too close to the excavated channels was liable to be eroded as the channels scoured and enlarged. In Pond A6 starter channels were not included in the design due to the cost of construction and the expected low benefits. A comparison of natural levee evolution from the Island Ponds and Pond A6 monitoring would be a useful guide for evaluating the desirability of side-casting.

Landscape Evolution

Marsh accretion was predicted using the Marsh98 analysis, a procedure that has been used widely to examine marsh sustainability to sea level rise across San Francisco Bay (e.g. Orr et al., 2003). The Marsh98 analysis is based on the mass balance calculations described by Krone (1987). This procedure assumes that the elevation of a marsh plain rises to colonization elevations at rates that depend on the (1) availability of suspended sediment and (2) depth and periods of inundation by high tides. When the level of an evolving marsh surface is low with respect to the tidal range, sedimentation rates may be high if the suspended sediment supply is sufficient. However, as the marsh surface rises through the tidal range, the frequency and duration of flooding by high tides is diminished so that the rate of sediment accumulation declines. Marsh98 implements these physical processes by calculating the amount of suspended sediment that deposits during each period of tidal inundation and sums that amount of deposition over the period of record.

Two revisions have been made to Marsh98 to more accurately represent physical conditions. These revisions include:

- Accelerating, nonlinear sea level rise is included. The sea level rise curves that were implemented were originally proposed by the National Research Council and modified by the USACE (2009), specifically NRC-I, -II and –III curves.
- Organic material is now added directly to the bed elevation at each tidal cycle. This method more accurately reflects the physical process with nonlinear sea level rise. Accretion due to organic material occurs when the marsh plain reaches a specified vegetation colonization elevation.

Model Input Parameters

Tidal Boundary Condition

The modeling was conducted relative to the tidal datum of NAVD88. The tidal boundary condition used for all model runs was a tidal month which has statistical characteristics identical to the observed tides at the Golden Gate. This boundary condition was then amplified using the Coyote Creek tidal datums to create a time series that could be applied to the Coyote Creek area. The title datums are shown in Table 6.

Table 6. Coyote Creek Tidal Datums

Datums	ft MLLW	ft NAVD	m NAVD
MHHW	9.01	7.49	2.27
MHW	8.42	6.90	2.10
MSL	4.92	3.40	1.04
MTL	4.83	3.31	1.01
NAVD88	1.52	0.00	0.00
MLW	1.24	-0.28	-0.09
MLLW	0.00	-1.52	-0.46

*NOAA Tides & Currents. Station ID: 9414575. MLLW to NAVD conversions are from NOAA unpublished (2005).

Habitat Zones

Seven habitat zones were chosen to represent different elevation within each breached pond. Table 7 presents these zones and elevations.

Table 7. Habitat Zones and Elevations

Habitat Zone	Elevation (relative to datums)	2017 Elevation (ft NAVD)	2017 Elevation (m NAVD)
Deep Subtidal	6 m below MLLW and deeper	< -21.16	< -6.45
Shallow Subtidal A	2 to 6 m below MLLW	-21.16 to -8.04	-6.45 to -2.45
Shallow Subtidal B	2 m below MLLW to MLLW	-8.04 to -1.48	-2.45 to -0.45
Intertidal Mudflat	MLLW to MTL + 0.3 m	-1.48 to 4.33	-0.45 to 1.32
Cordgrass Dominated	MTL + 0.3 m to MHW	4.33 to 6.96	1.32 to 2.12
Pickleweed Dominated	MHW to MHHW	6.96 to 7.51	2.12 to 2.29
Upland*	MHHW and above	> 7.51	> 2.29

*HTH provided the elevations for the all of the subtidal and tidal habitat zones. NAVD elevations refer to 2017.

Suspended Sediment Concentration

Suspended sediment concentration (SSC) varies throughout San Francisco Bay because of variations in wave conditions, proximity to mudflats, and river inputs. Monitoring data from Pond A21, just north of the site, were used to calibrate the SSC to be used in the model. The data was divided by starting elevations into three categories and then elevations over time were averaged for each group. Marsh98 was run with the three averaged starting elevations from the data and with three potential SSC (100, 200, and 300 mg/L).

For the first 6 to 12 months after breaching, the Island Ponds data tracks with the 300 mg/L suspended sediment concentration curve. However, the later elevation measurements show little increase in between time steps and track better with the 100 mg/L and 200 mg/L SSC curves. It is possible that the Pond A21 mudflats accreted rapidly in the first year as easily eroded material was remobilized, perhaps from the breach and outboard marsh, which increased the local SSC. Over time this supply of easily eroded material was exhausted and the subsequent accretion rate reflects more the ambient suspended sediment concentration in Coyote Creek. We are investigating the calibration data more closely and looking for evidence to test the variable SSC hypothesis. To represent the range of SSC, all three concentrations were modeled to bracket the possibilities. Subsequent runs will focus on the

100, 200 mg/L range and will also include a better description of the initial high rates following breaching. Long term decline in SSC should also be incorporated (Schoellhamer 2011).

Organic Matter

Marshes with high rates of organic matter production have been observed to accrete at faster rates than marshes composed primary of inorganic sediments (Orr et al., 2003). Marshes associated with the highest organic matter accretion rates are typically found in brackish or freshwater environments. Based on guidance from HTH, an organic matter accretion rate of 1 mm/yr was modeled for all scenarios when the marsh plain elevation reached MTL + 1ft (MTL + 0.3 m).

Rate of Sea Level Rise

A nonlinear sea level rise scenario based on the guidance provided by the USACE (2009) was used. This document recommends scenarios modifying curves proposed by the National Research Council to extrapolate intermediate and high sea level rise projections ("NRC-I" and "NRC-III", respectively). These scenarios project 0.5 m and 1.5 m of sea level rise over the next century depending on emissions. The high rate is similar to the draft State of California planning guidelines, which recommends planning for 16" of rise in the next 50 years and 55" in the next 100 years. For the Preliminary Alternatives reported here the NRC-III curve was used.

Phasing

Two phasing schemes were examined. The West Area First phasing scheme examined phased restoration beginning in the western most ponds. The Pond A12 First phasing scheme illustrates a phased restoration beginning with Pond A12 which is the lowest pond in the study area.

West Area First phasing scheme: the site evolution projections were phased by pond area with the west region (Ponds A9-A11) beginning in 2017, the east region (Pond A18) beginning in 2027, and the central region (Pond A12-A15) beginning in 2037. The division between the west and central region includes the realignment of the internal berm between Pond A9 and A11 which more accurately reflects the historic watershed.

Pond A12 First phasing scheme: site evolution projections were phased with restoration of Pond A12 beginning in 2017, followed by the westernmost ponds (A9-11) beginning in 2022, the eastern pond (Pond A18) beginning in 2027, and the remaining central ponds (Ponds A13-15) beginning in 2030. The intent of this alternate Pond A12 First phasing scheme is to restore tidal action to the Pond A12 as soon as possible to maximize accretion in the lowest pond in the study area. This phasing also accelerates restoration of the central area ponds (Pond A13-A15) by seven years as compared to the West Area First phasing scheme.

All runs ended in 2067. The different starting times place each region on a different part of the sea level rise curve. This means that without substantial suspended sediment, the central region will end up at lower elevations than the west (or east region) because it has fewer years to accrete and it begins on a steeper part of the sea level rise curve so sea level is increasing more rapidly.

Landscape Evolution Results

In general we have found with previous Marsh98 analysis in the South Bay (Orr, et.al., 2003) that:

- SSC of 25 mg/L are unlikely to sustain marshes for all scenarios, regardless of the input parameters. These concentrations are unlikely based on the Island Ponds monitoring data.
- SSC of 50 mg/L are unlikely to sustain marshes for all scenarios except for most favorable conditions (high initial bed elevation and organic accretion rate; intermediate rate of sea level rise). These concentrations are unlikely based on the Island Ponds monitoring data.
- SSC of 100 or 150 mg/L can sustain marshes only for particular combinations of initial bed elevation, organic accretion rate and rate of sea level rise. Varying any one of these four parameters can alter whether the model predicts vegetated or unvegetated Year 100 conditions. These are the likely range of concentrations based on the Island Ponds monitoring data.
- SSC of 300 mg/L are likely to sustain marshes for all scenarios but are unlikely to occur after the initial period of tidal restoration, as shown by the Island Pond monitoring data.

The model input parameters and predicted 2067 bed elevations for the 54 combinations of initial bed elevation, SSC, and phasing are summarized in Appendix A. The colors in the last column represent the habitat zone of that elevation where blue is subtidal, brown is mudflat, light green is cordgrass, and dark green is pickleweed.

The results presented here provide a first order estimate of marsh accretion rates for San Francisco Bay under a range of input conditions. However, it should be recognized that significant uncertainties remain with respect to future changes in sea level rise as well as the physical and biological processes which affect marsh accretion. In particular, the analysis does not include the influence of waves, which become more important as site size increases and availability of sediment diminishes. Sites that are more vulnerable to waves include those with bed elevations between vegetation colonization elevation and MHHW, e.g. those elevations close to cordgrass dominated elevations.

Spatial Evolution

The results summarized in Appendix A were used to create digital elevation models (DEMs) of the site in 2067 years for different SSC and different start years (Figures 5 to 10). Phasing was not used in these figures to provide understanding of the evolution of the individual ponds. The ability to reach colonization elevation is controlled by both SSC and the start year. The start year has two influences, firstly there is less time to accrete sediment before the end of the project in 2067, and secondly the tidal inundation starts at a higher sea level and at a time when the sea level is rising faster.

Start Year 2017: Figure 5 and 6 show the likely evolution of the ponds by 2067 for a SSC of 100 and 200mg/L and a start date of 2017. It clearly shows for 100 mg/L none of the ponds attain elevations that allow for colonization and remain mudflats – all the sedimentation that is shown is due to inorganic sediment deposition at lower elevations, which is well-produced in Marsh98. The spatial pattern within the ponds reflects the initial start elevation and reflects how deeply subsided Pond A12 is, particularly adjacent to Alviso Slough and the Pond A12 inboard levee. For SSC of 200 mg/L nearly all the ponds reach colonization elevation, either cordgrass or pickleweed elevations.

Start Year 2027: Figure 7 and 8 show the likely evolution of the ponds by 2067 with a start date of 2027. For SSC of 100mg/L the mudflats within the ponds are lower than with a start date of 2017, as there has been less time to accrete. For SSC of 200 mg/L nearly all the ponds reach colonization elevation, but only attain cordgrass elevations.

Start Year 2037: Figure 9 and 10 show the likely evolution of the ponds by 2067 with a start date of 2037, a period of only 30 years. The pattern for both SSCs are the same as before but shifted lower in elevation. With the 200mg/L plot (Figure 10) there are areas in Pond A12 which do not achieve vegetation colonization elevation and remain mudflat.

Phased Evolution

Figures 11 and 12 show projections of the evolution of the site for the West Area First phasing scheme with varying start dates for the different Ponds with the west region (Ponds A9-A11) beginning in 2017, the east region (Pond A18) beginning in 2027, and the central region (Pond A12-A15) beginning in 2037. Figure 11 (SSC=100 mg/L) shows the impact of restoring tidal influence to the most deeply subsided ponds last; the elevation in Pond A12 remains low mudflat and shallow subtidal. Figure 12 (SSC=200 mg/L) shows the same basic pattern but all the elevations are higher, mostly achieving colonization elevations, except for Pond A12. This clearly shows the influence of phasing on the success in restoring a complete marsh in Ponds A9 to A15. Changing the order of restoration will have a significant impact on the outcome of the project in 2067.

Figures 13 and 14 illustrate the evolutionary projections for the Pond A12 First phasing scheme with the start dates for Pond A12 beginning in 2017, followed by west region (Pond A9-A11) in 2022, eastern region (Pond A18) in 2027, and the remaining central region ponds (Ponds A13-15) in 2030. Figure 13 (SSC=100 mg/L) shows the results of restoring the deeply subsided Pond A12 first and moving the restoration of Ponds A13-A15 up to 2030. Areas in Pond A12 that remained as shallow subtidal in the West Area First phasing scheme become low mudflat. Figure 14 (SSC=200 mg/L) illustrates that with higher sediment concentrations, restoration of Pond A12 beginning in 2017 allows this pond to reach cordgrass and pickleweed colonization elevations by 2067. Moving restoration of the remaining central area ponds (Ponds A13-15) up to 2030 allows areas of these ponds that remained as intertidal mudflat when restored in 2037, to reach low cordgrass colonization elevations by 2067.

Figures 15 and 16 present medium and large fill transitional alternatives with the projected evolution under Pond A12 First phasing scheme with the higher (200 mg/L) suspended sediment concentration.

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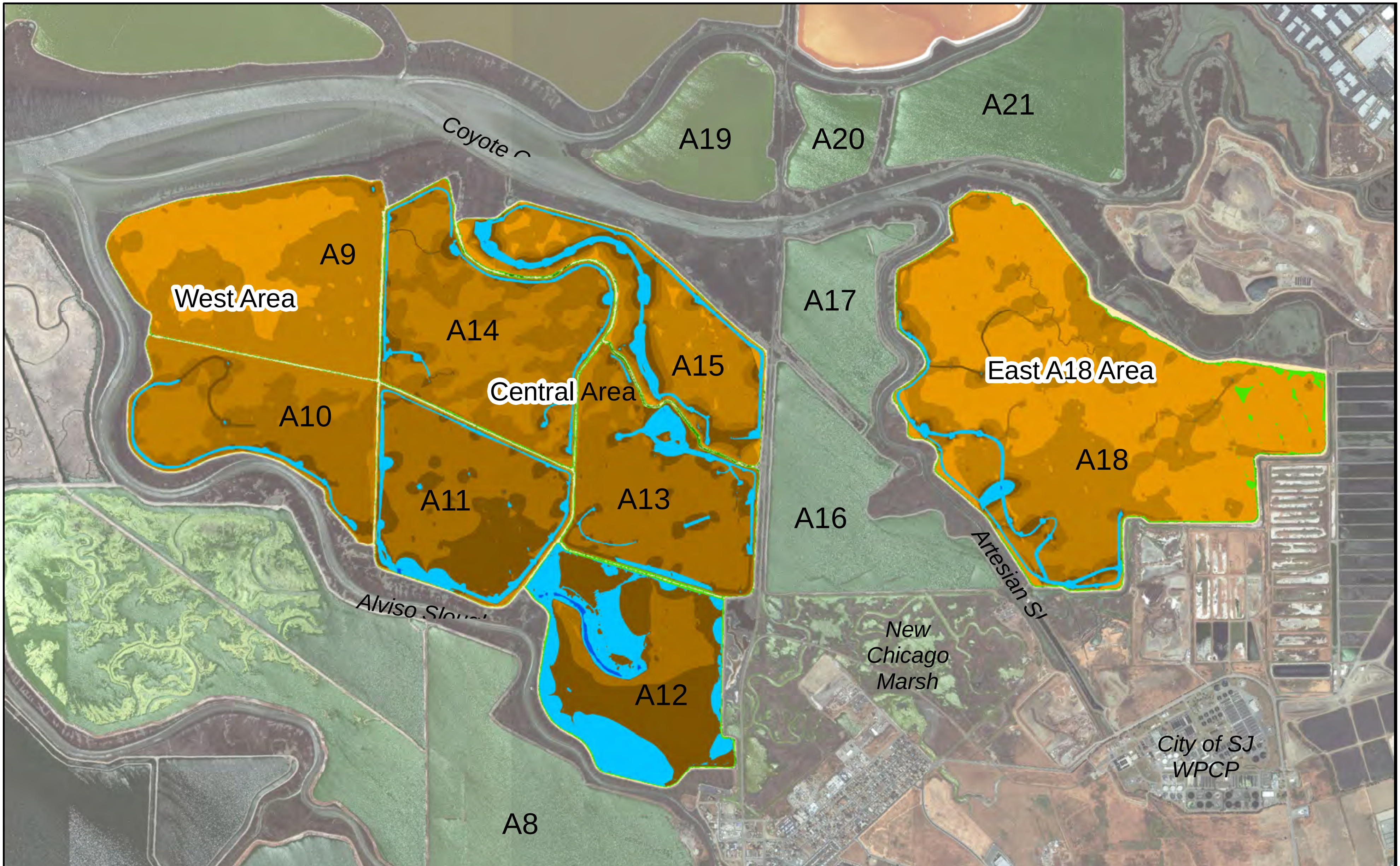
Appendix A

Summary of Landscape Evolution Projections

Habitat Zone	Elevation (relative to datums)
Deep Subtidal	6 m below MLLW and deeper
Shallow Subtidal A	2 to 6 m below MLLW
Shallow Subtidal B	2 m below MLLW to MLLW
Intertidal Mudflat	MLLW to MTL + 0.3 m
Cordgrass Dominated	MTL + 0.3 m to MHW
Pickleweed Dominated	MHW to MHHW

Run ID	Start Year	Co (mg/L)	2017 Elevations (ft NAVD)	2067 Elevation (ft NAVD)	Change in Elevation (ft)	MHHW 2067 (ft NAVD)	2067 Elevations - MHHW (ft)
1	2017	100	-12.30	-8.48	3.82	9.62	18.10
2	2017	100	-3.28	0.54	3.82	9.62	9.07
3	2017	100	0.00	3.53	3.53	9.62	6.08
4	2017	100	5.74	7.55	1.81	9.62	2.06
5	2017	100	7.38	8.58	1.20	9.62	-1.04
6	2017	100	9.84	9.62	-0.22	9.62	0.00
7	2017	200	-12.30	2.99	15.29	9.62	6.62
8	2017	200	-3.28	8.31	11.59	9.62	-1.30
9	2017	200	0.00	9.03	9.03	9.62	-0.58
10	2017	200	5.74	9.62	3.88	9.62	0.00
11	2017	200	7.38	9.62	2.24	9.62	0.00
12	2017	200	9.84	9.62	-0.22	9.62	0.00
13	2017	300	-12.30	9.62	21.92	9.62	0.00
14	2017	300	-3.28	9.62	12.90	9.62	0.00
15	2017	300	0.00	9.62	9.62	9.62	0.00
16	2017	300	5.74	9.62	3.88	9.62	0.00
17	2017	300	7.38	9.62	2.24	9.62	0.00
18	2017	300	9.84	9.62	-0.22	9.62	0.00
19	2027	100	-12.30	-9.25	3.05	9.61	18.86
20	2027	100	-3.28	-0.22	3.06	9.61	9.83
21	2027	100	0.00	2.87	2.87	9.61	6.74
22	2027	100	5.74	7.22	1.48	9.61	2.39
23	2027	100	7.38	8.34	0.96	9.61	-1.27
24	2027	100	9.84	9.61	-0.23	9.61	0.00

Run ID	Start Year	Co (mg/L)	2017 Elevations (ft NAVD)	2067 Elevation (ft NAVD)	Change in Elevation (ft)	MHHW 2067 (ft NAVD)	2067 Elevations - MHHW (ft)
25	2027	200	-12.30	-0.05	12.25	9.61	9.66
26	2027	200	-3.28	7.04	10.32	9.61	2.57
27	2027	200	0.00	8.15	8.15	9.61	-1.46
28	2027	200	5.74	9.39	3.65	9.61	-0.22
29	2027	200	7.38	9.61	2.23	9.61	0.00
30	2027	200	9.84	9.61	-0.23	9.61	0.00
31	2027	300	-12.30	8.81	21.11	9.61	-0.80
32	2027	300	-3.28	9.61	12.89	9.61	0.00
33	2027	300	0.00	9.61	9.61	9.61	0.00
34	2027	300	5.74	9.61	3.87	9.61	0.00
35	2027	300	7.38	9.61	2.23	9.61	0.00
36	2027	300	9.84	9.61	-0.23	9.61	0.00
37	2037	100	-12.30	-10.01	2.29	9.61	19.63
38	2037	100	-3.28	-0.99	2.29	9.61	10.60
39	2037	100	0.00	2.17	2.17	9.61	7.44
40	2037	100	5.74	6.86	1.12	9.61	2.75
41	2037	100	7.38	8.10	0.72	9.61	-1.52
42	2037	100	9.84	9.61	-0.23	9.61	0.00
43	2037	200	-12.30	-3.13	9.17	9.61	12.74
44	2037	200	-3.28	5.24	8.52	9.61	4.38
45	2037	200	0.00	6.91	6.91	9.61	2.70
46	2037	200	5.74	8.77	3.03	9.61	-0.84
47	2037	200	7.38	9.26	1.88	9.61	-0.35
48	2037	200	9.84	9.61	-0.23	9.61	0.00
49	2037	300	-12.30	6.15	18.45	9.61	3.47
50	2037	300	-3.28	9.01	12.29	9.61	-0.61
51	2037	300	0.00	9.40	9.40	9.61	-0.21
52	2037	300	5.74	9.61	3.87	9.61	0.00
53	2037	300	7.38	9.61	2.23	9.61	0.00
54	2037	300	9.84	9.61	-0.23	9.61	0.00



Initial conditions. No Marsh98 run. No fill.

N

0 550 1,100 2,200 3,300 4,400 5,500 Feet

Habitat Zones (ft NAVD)

- Deep Subtidal (< -21.2)
- Shallow Subtidal A (-21.2 to -8.0)
- Shallow Subtidal B (-8.0 to -1.5)
- Intertidal Mudflat low (-1.5 to 0)
- Intertidal Mudflat mid low (0 to 1.3)
- Intertidal Mudflat mid high (1.3 to 3.0)
- Intertidal Mudflat high (3.0 to 4.3)
- Cordgrass Dominated low (4.3 to 5.6)
- Cordgrass Dominated high (5.6 to 7.0)
- Pickleweed Dominated (7.0 to 7.5)
- Upland (> 7.5)

figure 1

Shoreline Study Alternatives

Preliminary Alternative 1 Transitional - Upland Fill Footprint

Proj. # 211259

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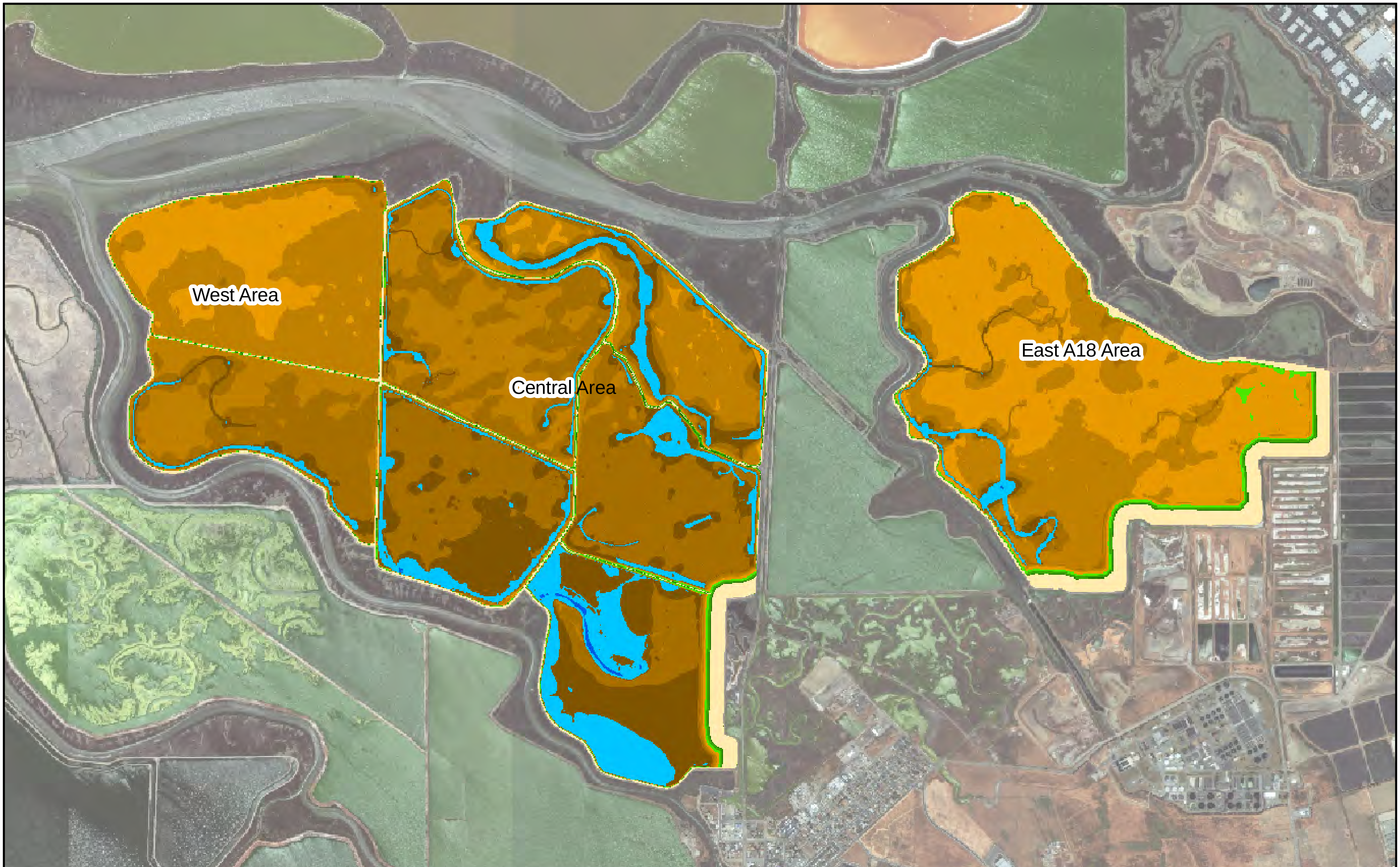

Initial conditions. No Marsh98 run. Fill 1:30.

N

0 550 1,100 2,200 3,300 4,400 5,500 Feet

Habitat Zones (ft NAVD)

- Deep Subtidal (< -21.2)
- Shallow Subtidal A (-21.2 to -8.0)
- Shallow Subtidal B (-8.0 to -1.5)
- Intertidal Mudflat low (-1.5 to 0)
- Intertidal Mudflat mid low (0 to 1.3)
- Intertidal Mudflat mid high (1.3 to 3.0)
- Intertidal Mudflat high (3.0 to 4.3)
- Cordgrass Dominated low (4.3 to 5.6)
- Cordgrass Dominated high (5.6 to 7.0)
- Pickleweed Dominated (7.0 to 7.5)
- Upland (> 7.5)

figure 2

Shoreline Study Alternatives

Preliminary Alternative 2 Transitional - Upland Fill Footprint

Proj. # 211259

ESA PWA

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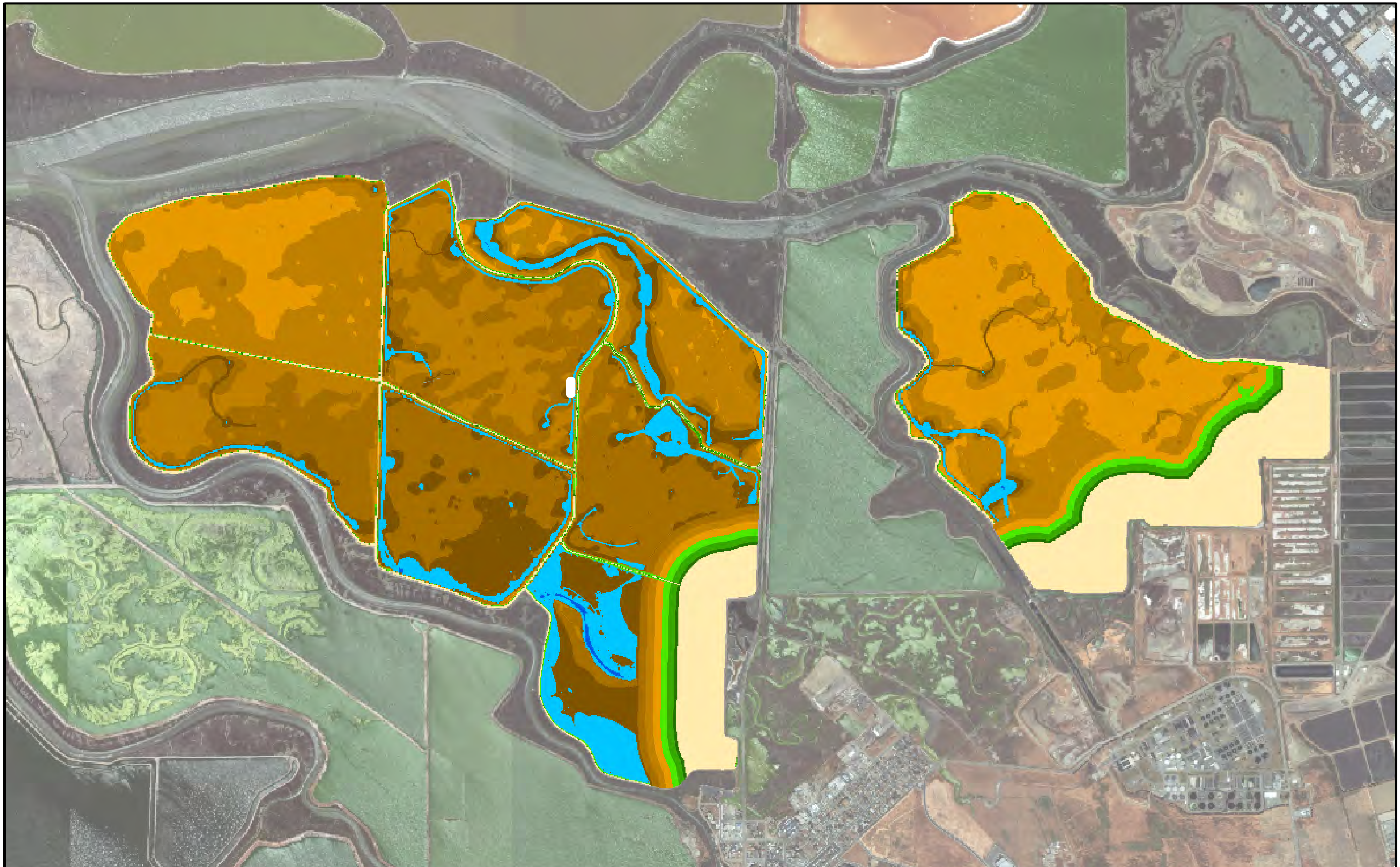

Initial conditions. No Marsh98 run. Fill 1:100.

N

0 550 1,100 2,200 3,300 4,400 5,500 Feet

Habitat Zones (ft NAVD)

- Deep Subtidal (< -21.2)
- Shallow Subtidal A (-21.2 to -8.0)
- Shallow Subtidal B (-8.0 to -1.5)
- Intertidal Mudflat low (-1.5 to 0)
- Intertidal Mudflat mid low (0 to 1.3)
- Intertidal Mudflat mid high (1.3 to 3.0)
- Intertidal Mudflat high (3.0 to 4.3)
- Cordgrass Dominated low (4.3 to 5.6)
- Cordgrass Dominated high (5.6 to 7.0)
- Pickleweed Dominated (7.0 to 7.5)
- Upland (> 7.5)

figure 3

Shoreline Study Alternatives

Preliminary Alternative 3 Transitional - Upland Fill Footprint

Proj. # 211259

ESA PWA

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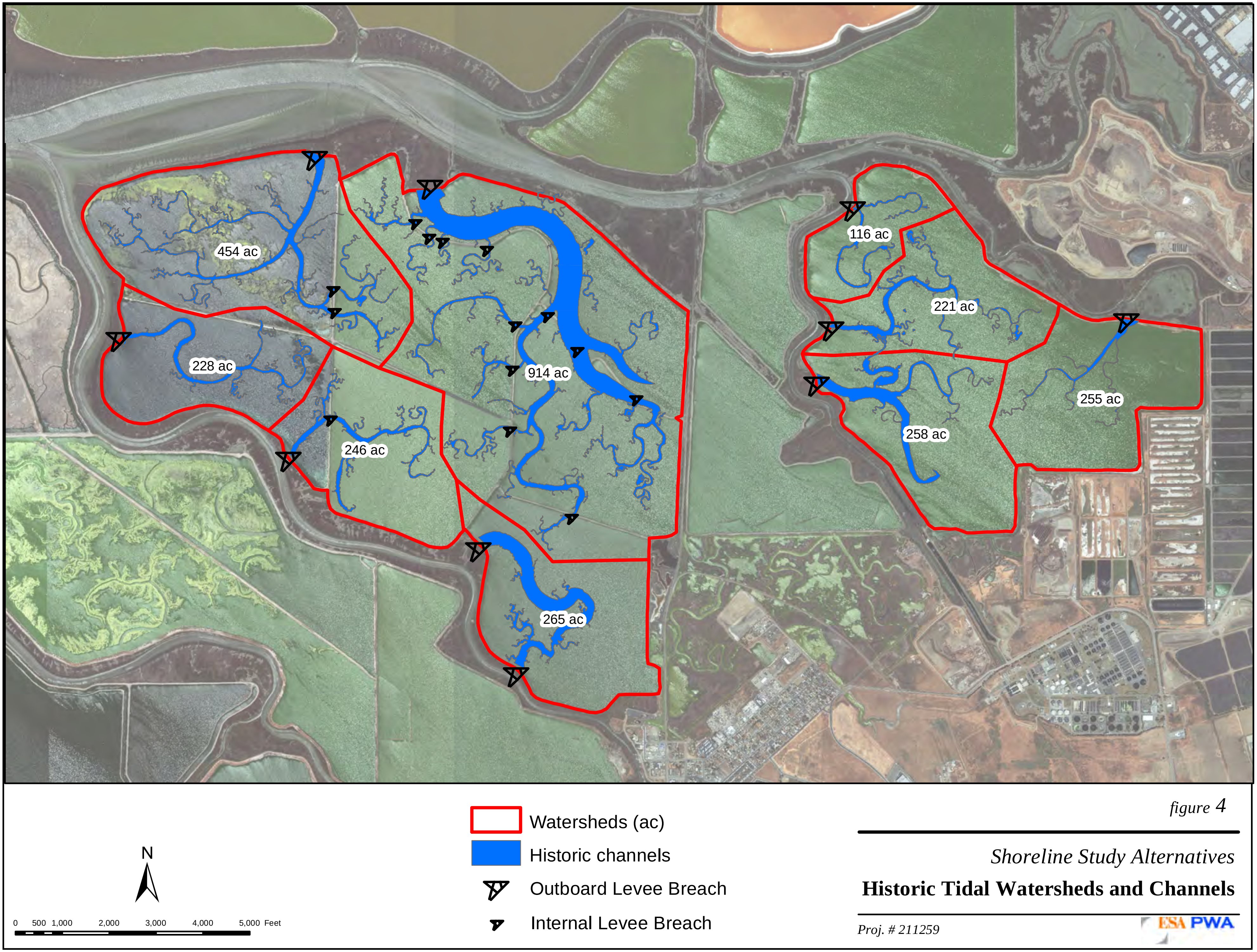

figure 4

Shoreline Study Alternatives

Historic Tidal Watersheds and Channels

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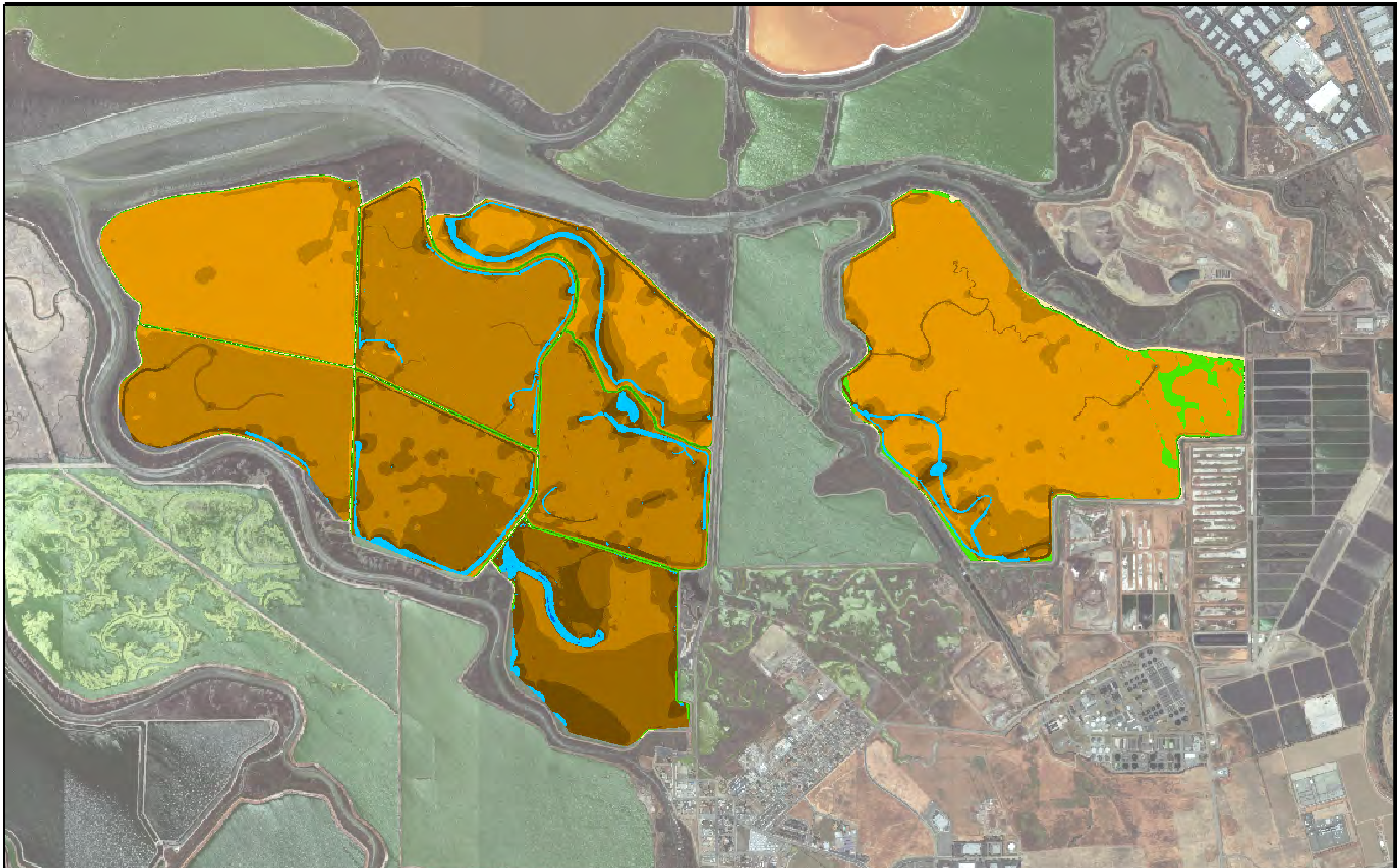

C0 = 100 mg/L, NRC-III, organics = 1 mm/yr
Start all areas in 2017

N

0 1,000 2,000 4,000 6,000 Feet

Habitat Zones
- Deep Subtidal
- Shallow Subtidal A
- Shallow Subtidal B
- Intertidal Mudflat low
- Intertidal Mudflat mid low
- Intertidal Mudflat mid high
- Intertidal Mudflat high
- Cordgrass Dominated low
- Cordgrass Dominated high
- Pickleweed Dominated
- Upland

figure 5

Shoreline Study Alternatives

2067 Marsh Elevations with C0 = 100 mg/L and 2017 Start

Proj. # 211259

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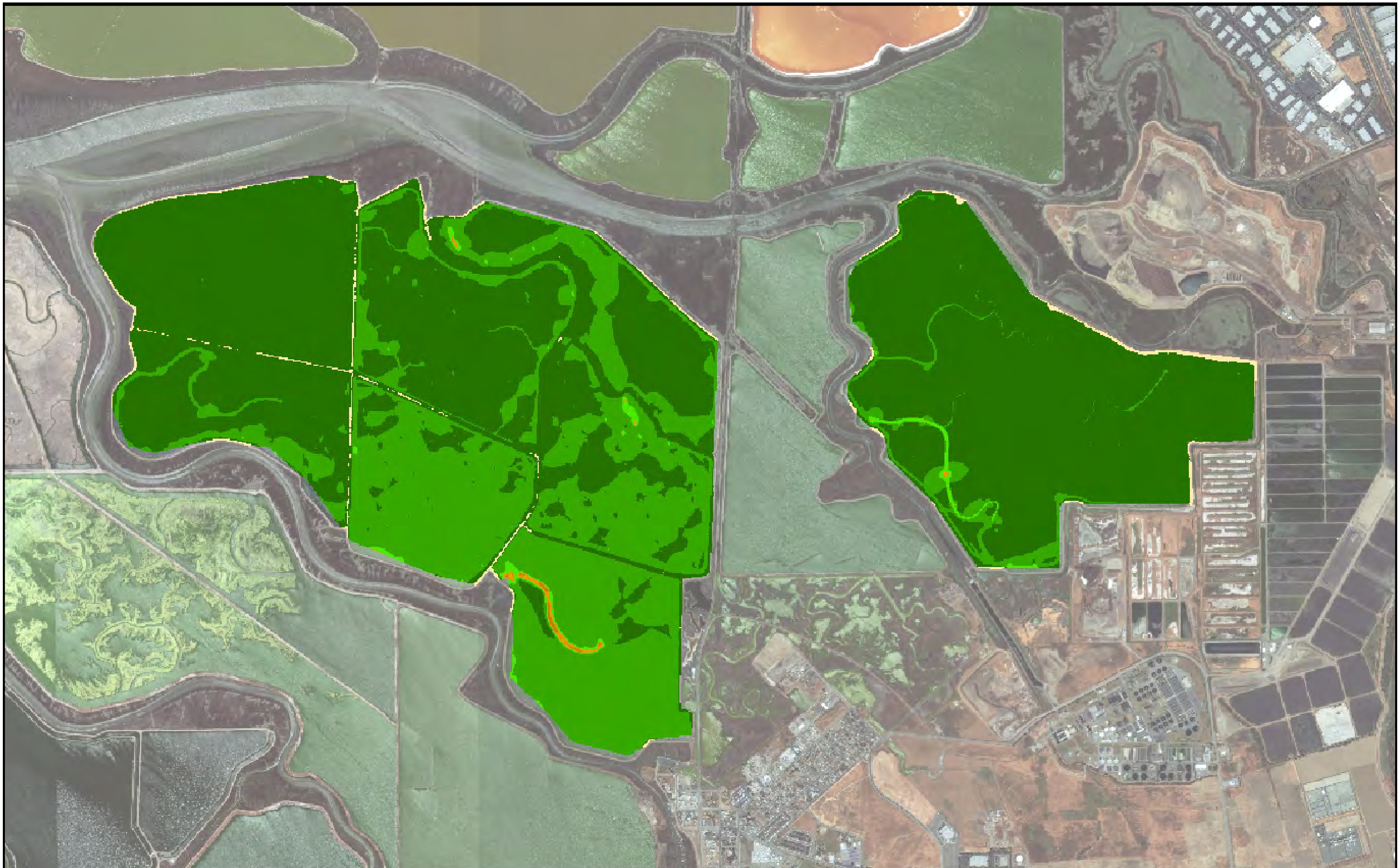

C0 = 200 mg/L, NRC-III, organics = 1 mm/yr
Start all areas in 2017

N

0 1,000 2,000 4,000 6,000 Feet

Habitat Zones

- Deep Subtidal
- Shallow Subtidal A
- Shallow Subtidal B
- Intertidal Mudflat low
- Intertidal Mudflat mid low
- Intertidal Mudflat mid high
- Intertidal Mudflat high
- Cordgrass Dominated low
- Cordgrass Dominated high
- Pickleweed Dominated
- Upland

figure 6

Shoreline Study Alternatives

2067 Marsh Elevations with C0 = 200 mg/L and 2017 Start

Proj. # 211259

ESA PWA

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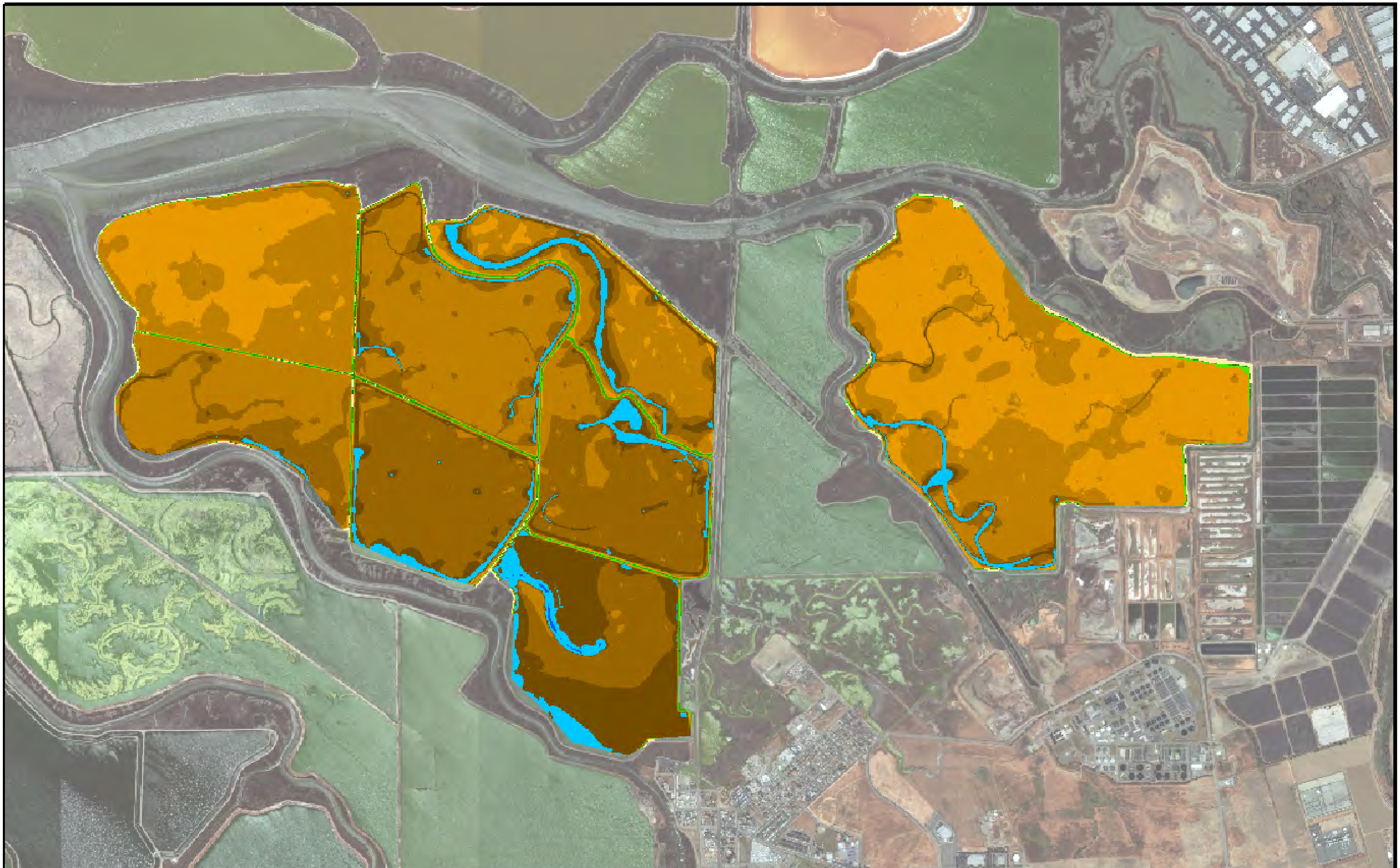

C0 = 100 mg/L, NRC-III, organics = 1 mm/yr
Start all areas in 2027

Habitat Zones

- Deep Subtidal
- Shallow Subtidal A
- Shallow Subtidal B
- Intertidal Mudflat low
- Intertidal Mudflat mid low
- Intertidal Mudflat mid high
- Intertidal Mudflat high
- Cordgrass Dominated low
- Cordgrass Dominated high
- Pickleweed Dominated
- Upland

figure 7

Shoreline Study Alternatives

2067 Marsh Elevations with C0 = 100 mg/L and 2027 Start

Proj. # 211259

ESA PWA

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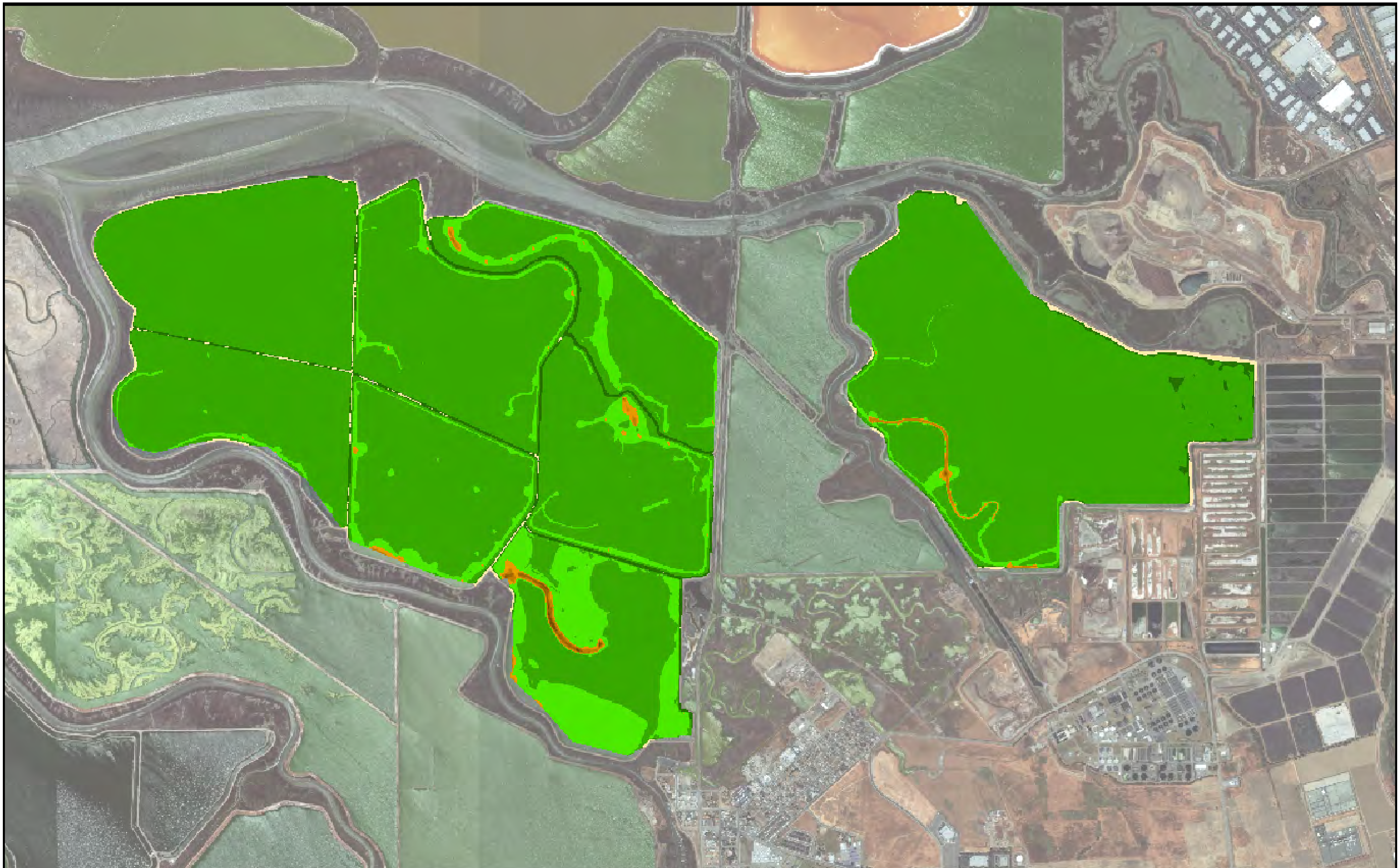

C0 = 200 mg/L, NRC-III, organics = 1 mm/yr
Start all areas in 2027

N

0 1,000 2,000 4,000 6,000 Feet

Habitat Zones

- Deep Subtidal
- Shallow Subtidal A
- Shallow Subtidal B
- Intertidal Mudflat low
- Intertidal Mudflat mid low
- Intertidal Mudflat mid high
- Intertidal Mudflat high
- Cordgrass Dominated low
- Cordgrass Dominated high
- Pickleweed Dominated
- Upland

figure 8

Shoreline Study Alternatives

2067 Marsh Elevations with C0 = 200 mg/L and 2027 Start

Proj. # 211259

ESA PWA

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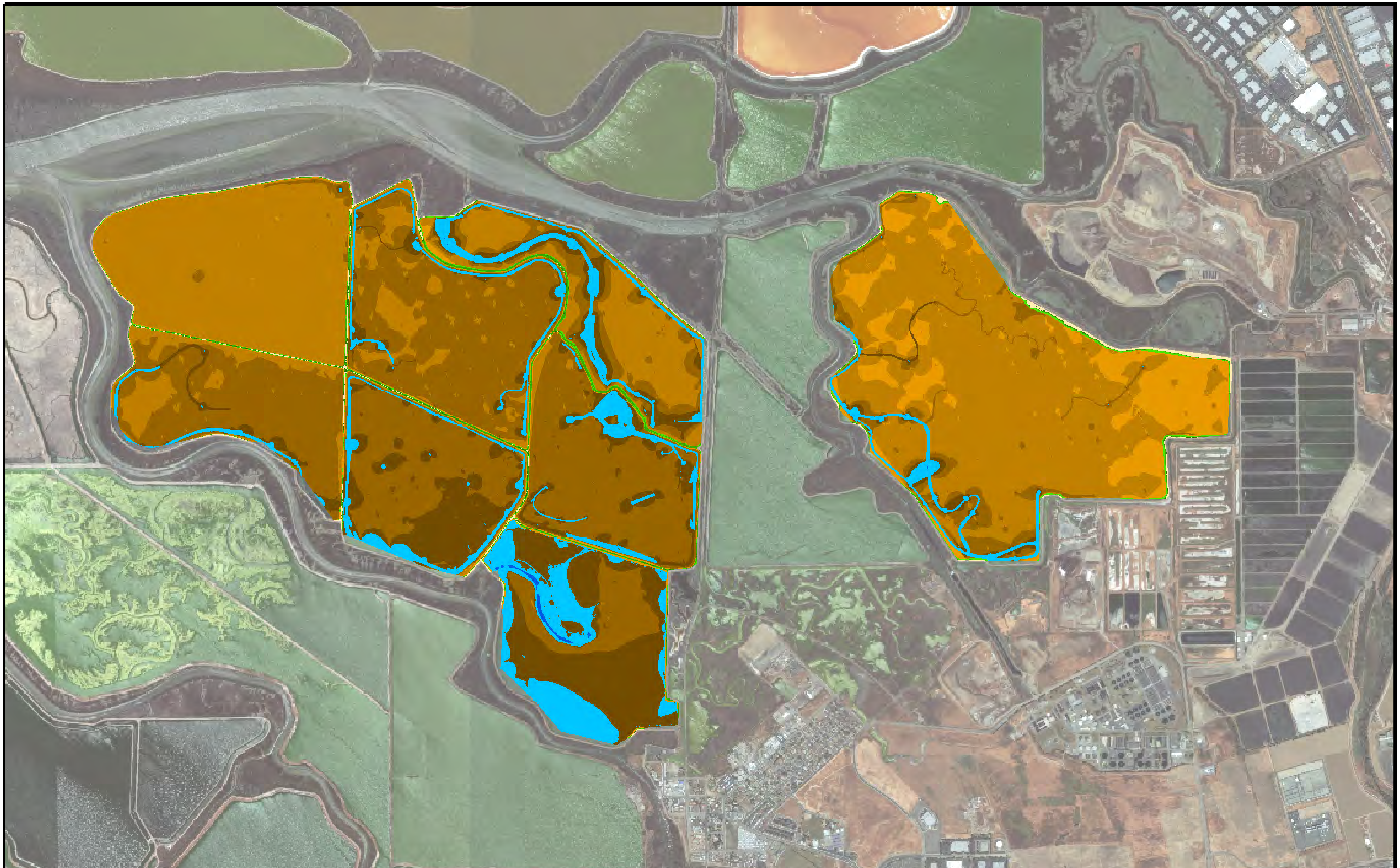

C0 = 100 mg/L, NRC-III, organics = 1 mm/yr
Start all areas in 2037

N

0 1,000 2,000 4,000 6,000 Feet

Habitat Zones

- Deep Subtidal
- Shallow Subtidal A
- Shallow Subtidal B
- Intertidal Mudflat low
- Intertidal Mudflat mid low
- Intertidal Mudflat mid high
- Intertidal Mudflat high
- Cordgrass Dominated low
- Cordgrass Dominated high
- Pickleweed Dominated
- Upland

figure 9

Shoreline Study Alternatives

2067 Marsh Elevations with C0 = 100 mg/L and 2037 Start

Proj. # 211259

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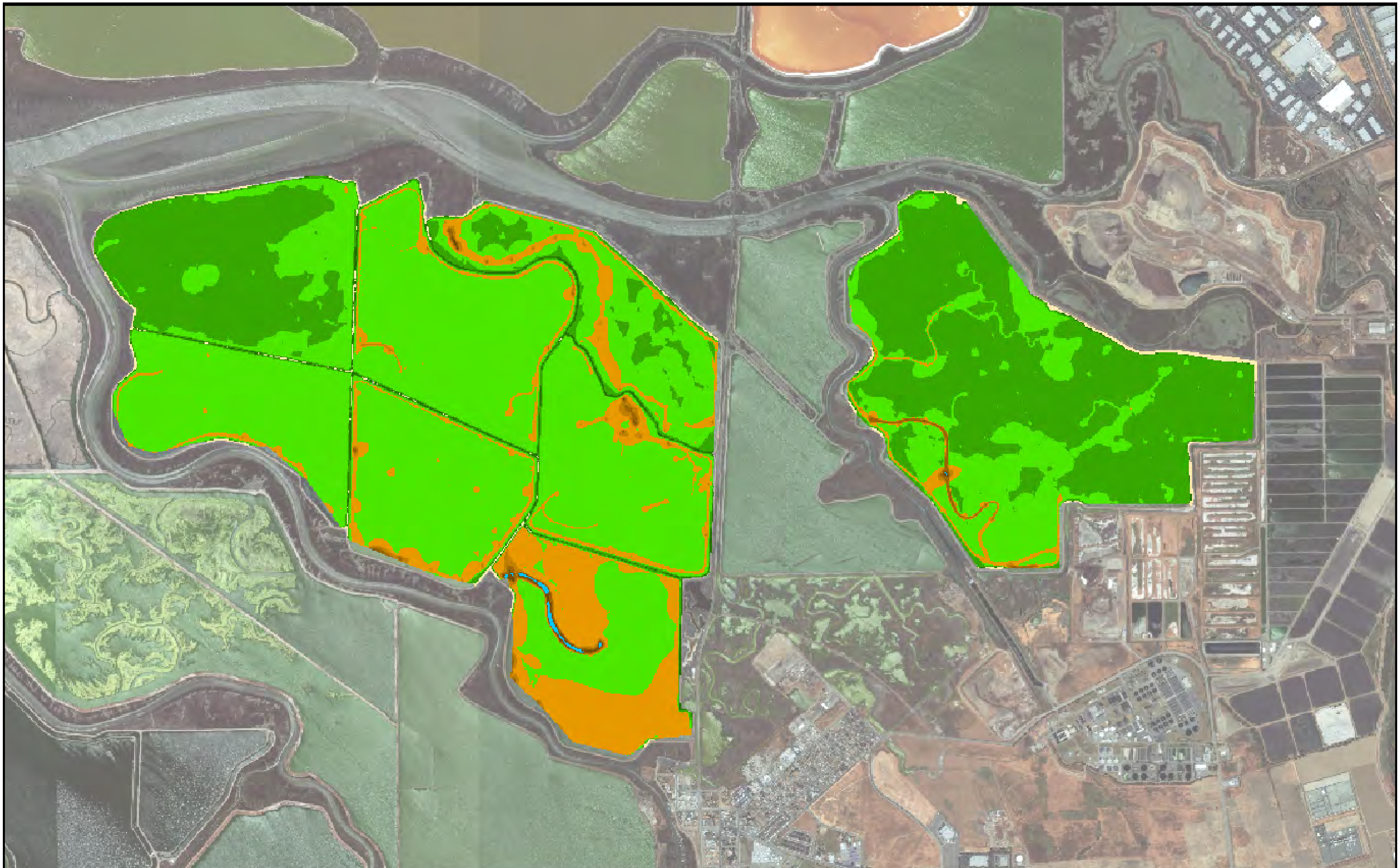

C0 = 200 mg/L, NRC-III, organics = 1 mm/yr
Start all areas in 2037

N

0 1,000 2,000 4,000 6,000 Feet

Habitat Zones

- Deep Subtidal
- Shallow Subtidal A
- Shallow Subtidal B
- Intertidal Mudflat low
- Intertidal Mudflat mid low
- Intertidal Mudflat mid high
- Intertidal Mudflat high
- Cordgrass Dominated low
- Cordgrass Dominated high
- Pickleweed Dominated
- Upland

figure 10

Shoreline Study Alternatives

2067 Marsh Elevations with C0 = 200 mg/L and 2037 Start

Proj. # 211259

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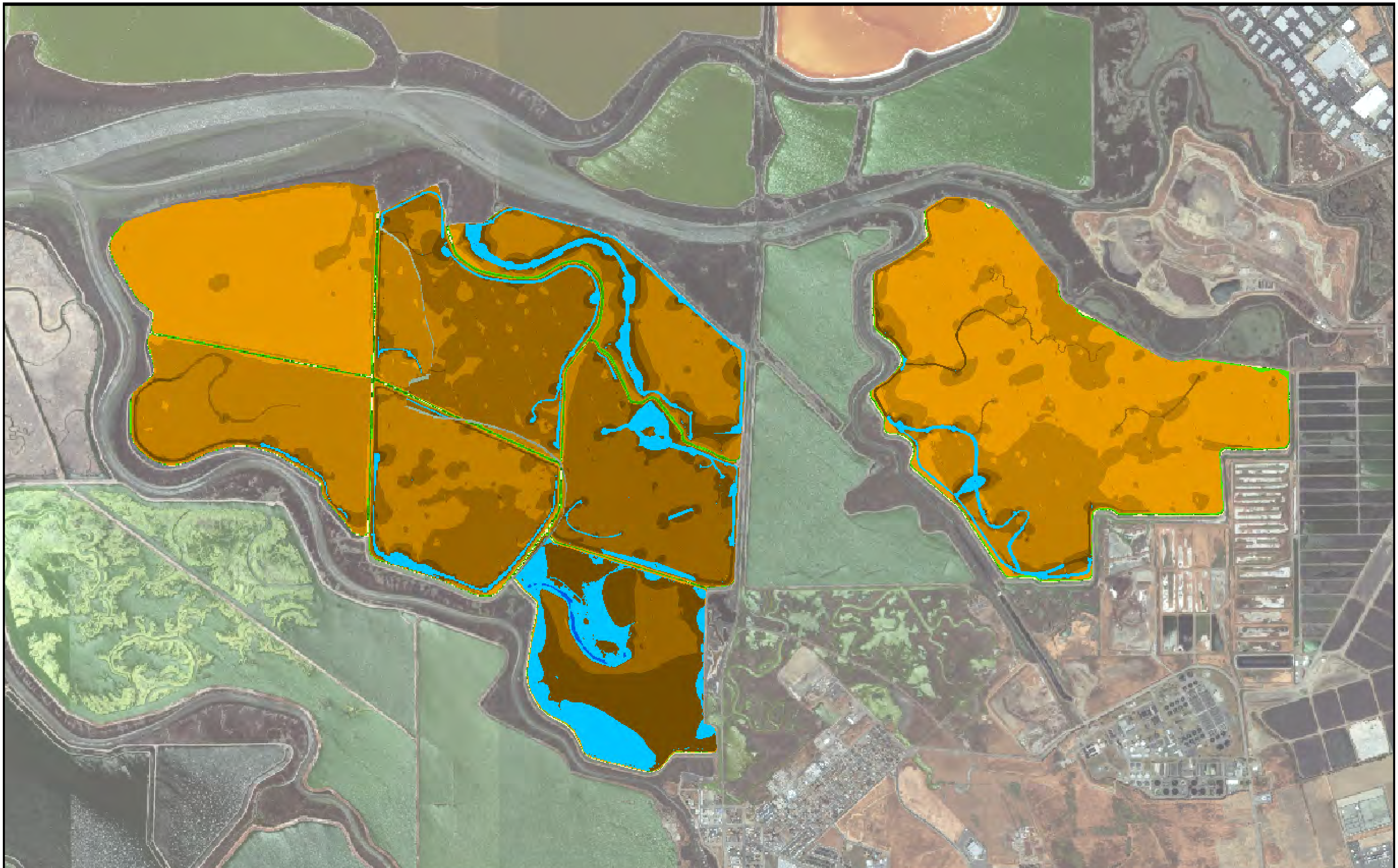

C0 = 100 mg/L, NRC-III, organics = 1 mm/yr
Start West Area in 2017, East Area (A18) in 2027,
and Central Area in 2037

N

0 1,000 2,000 4,000 6,000 Feet

Habitat Zones

- Deep Subtidal
- Shallow Subtidal A
- Shallow Subtidal B
- Intertidal Mudflat low
- Intertidal Mudflat mid low
- Intertidal Mudflat mid high
- Intertidal Mudflat high
- Cordgrass Dominated low
- Cordgrass Dominated high
- Pickleweed Dominated
- Upland

figure 11

Shoreline Study Alternatives

2067 Marsh Elevations with C0 = 100 mg/L

Proj. # 211259

ESA PWA

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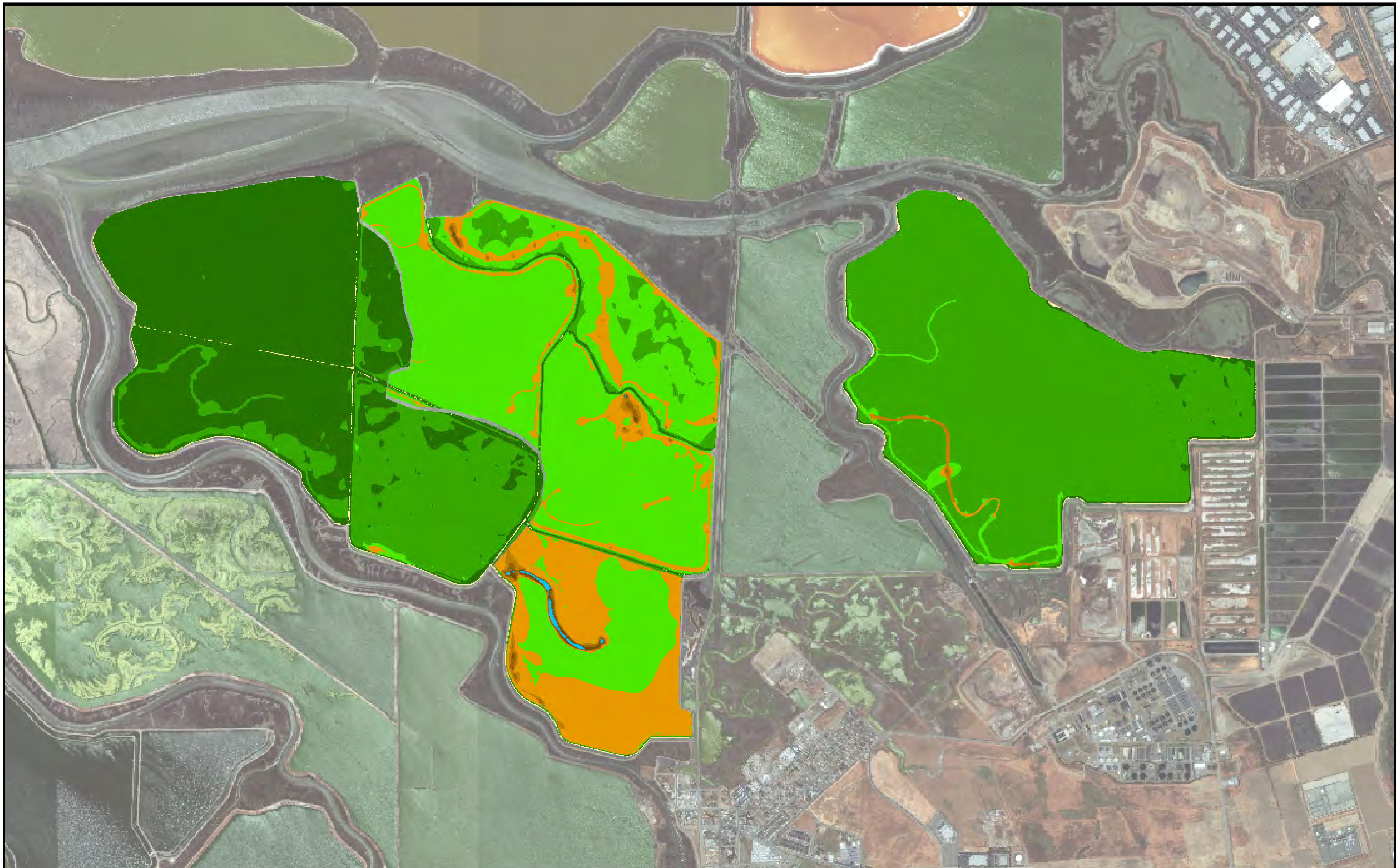

C0 = 200 mg/L, NRC-III, organics = 1 mm/yr
Start West Area in 2017, East Area (A18) in 2027, and Central Area in 2037

N

0 1,000 2,000 4,000 6,000 Feet

Habitat Zones

- Deep Subtidal
- Shallow Subtidal A
- Shallow Subtidal B
- Intertidal Mudflat low
- Intertidal Mudflat mid low
- Intertidal Mudflat mid high
- Intertidal Mudflat high
- Cordgrass Dominated low
- Cordgrass Dominated high
- Pickleweed Dominated
- Upland

figure 12

Shoreline Study Alternatives

2067 Marsh Elevations with C0 = 200 mg/L

Proj. # 211259

ESA PWA

J:\211259 Shoreline\Mxds\50yrWestEastCentralv2\C0=200.mxd

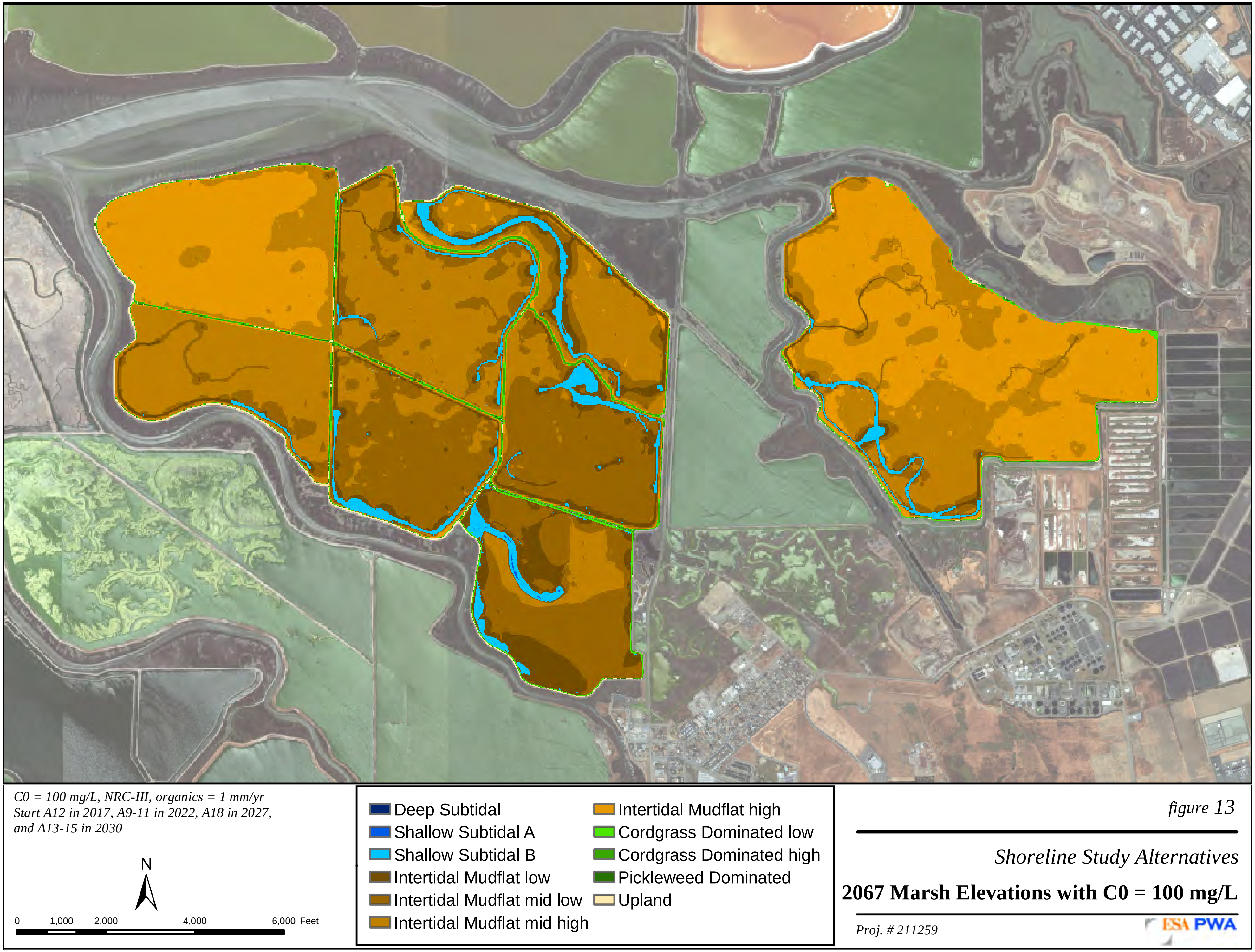

figure 13

Shoreline Study Alternatives

2067 Marsh Elevations with C0 = 100 mg/L

Proj. # 211259

ESA PWA

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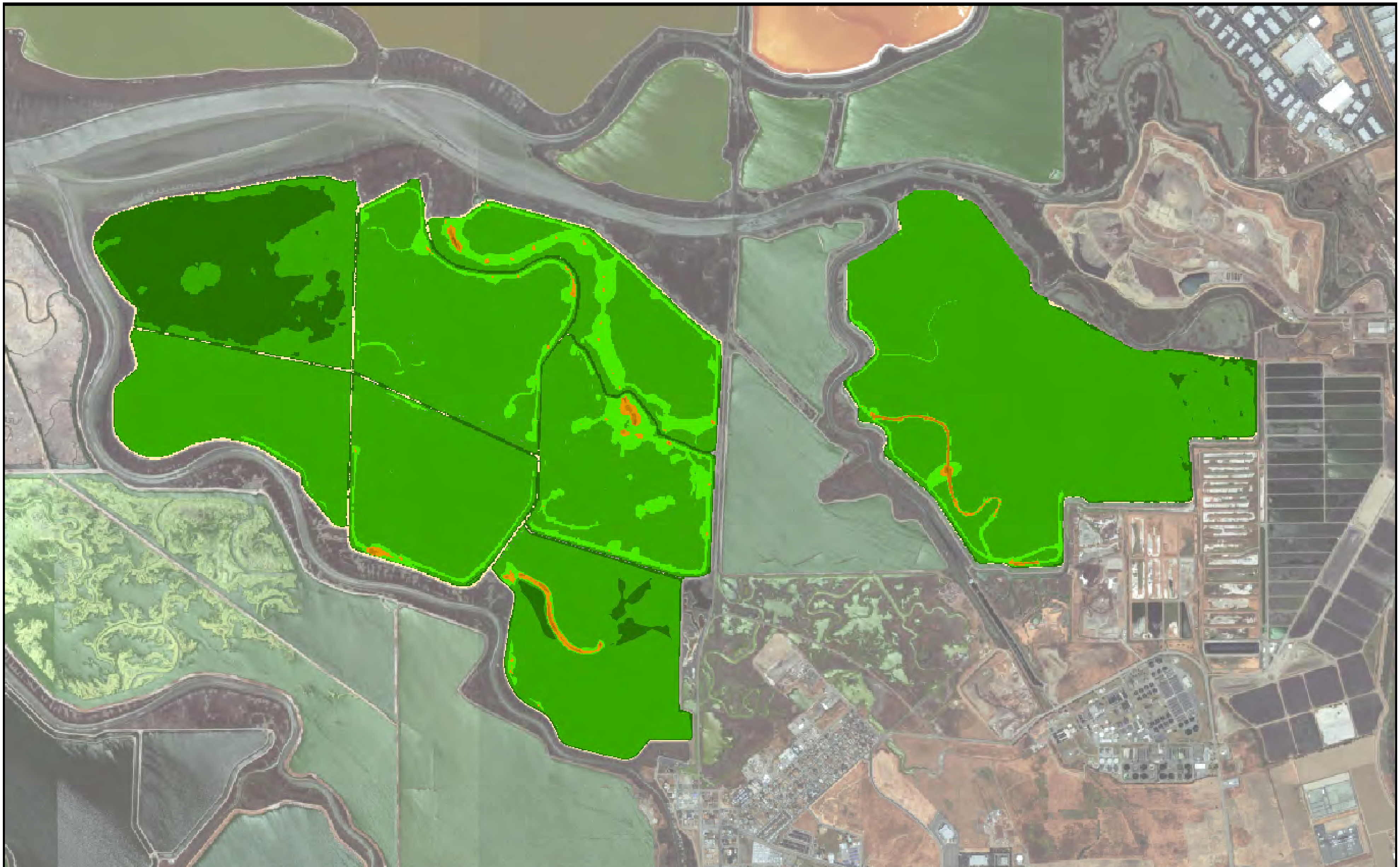

C0 = 200 mg/L, NRC-III, organics = 1 mm/yr
Start A12 in 2017, A9-11 in 2022, A18 in 2027,
and A13-15 in 2030

N

0 1,000 2,000 4,000 6,000 Feet

- Deep Subtidal
- Shallow Subtidal A
- Shallow Subtidal B
- Intertidal Mudflat low
- Intertidal Mudflat mid low
- Intertidal Mudflat mid high
- Intertidal Mudflat high
- Cordgrass Dominated low
- Cordgrass Dominated high
- Pickleweed Dominated
- Upland

figure 14

Shoreline Study Alternatives

2067 Marsh Elevations with C0 = 200 mg/L

Proj. # 211259

ESA PWA

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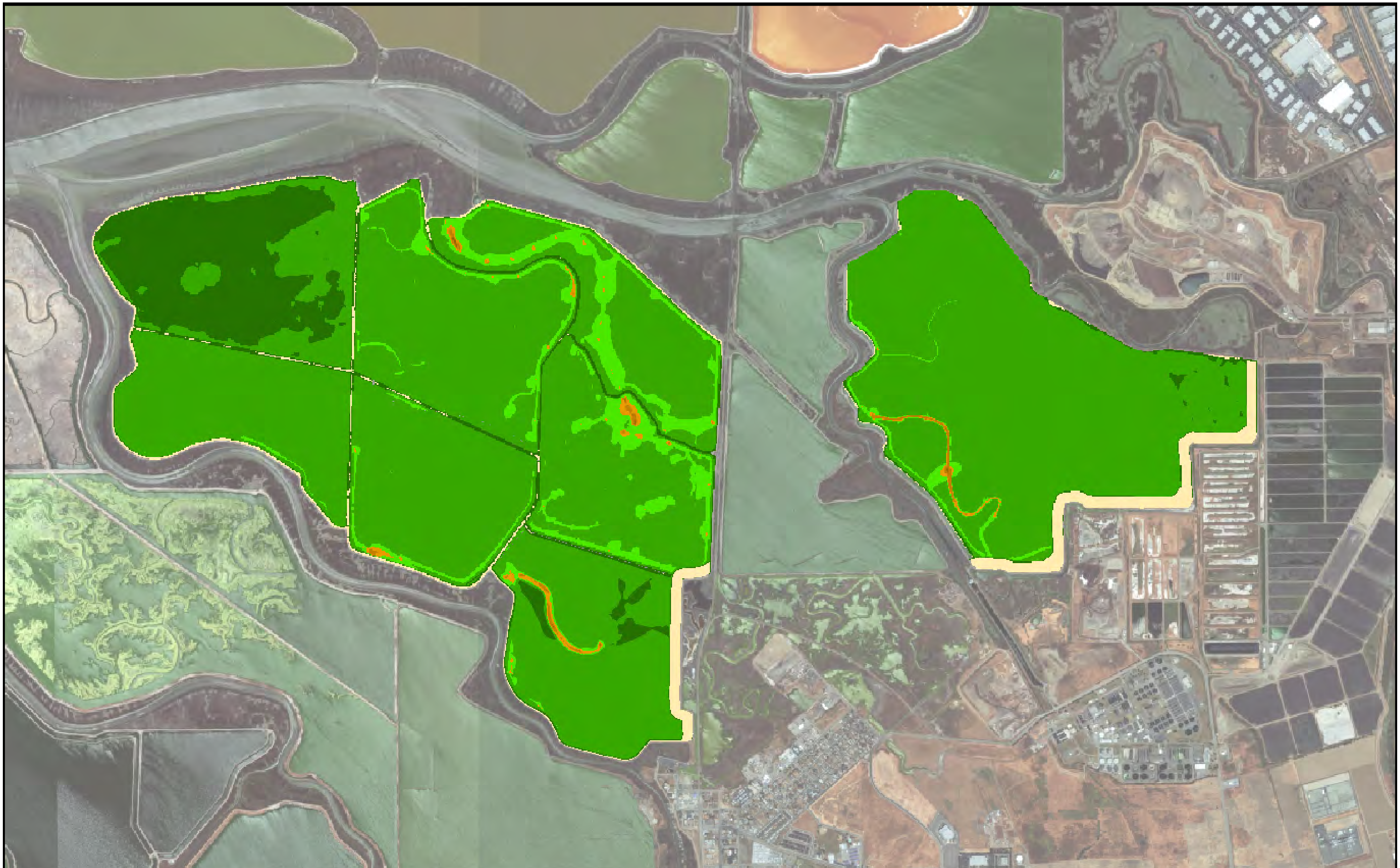

C0 = 200 mg/L, NRC-III, organics = 1 mm/yr
Start A12 in 2017, A9-11 in 2022, A18 in 2027,
and A13-15 in 2030. Fill 1:30

N

0 1,000 2,000 4,000 6,000 Feet

- Deep Subtidal
- Shallow Subtidal A
- Shallow Subtidal B
- Intertidal Mudflat low
- Intertidal Mudflat mid low
- Intertidal Mudflat mid high
- Intertidal Mudflat high
- Cordgrass Dominated low
- Cordgrass Dominated high
- Pickleweed Dominated
- Upland

figure 15

Shoreline Study Alternatives

2067 Marsh Elevations with Prelim
Alt 2 Transitional - Upland Fill Footprint

Proj. # 211259

ESA PWA

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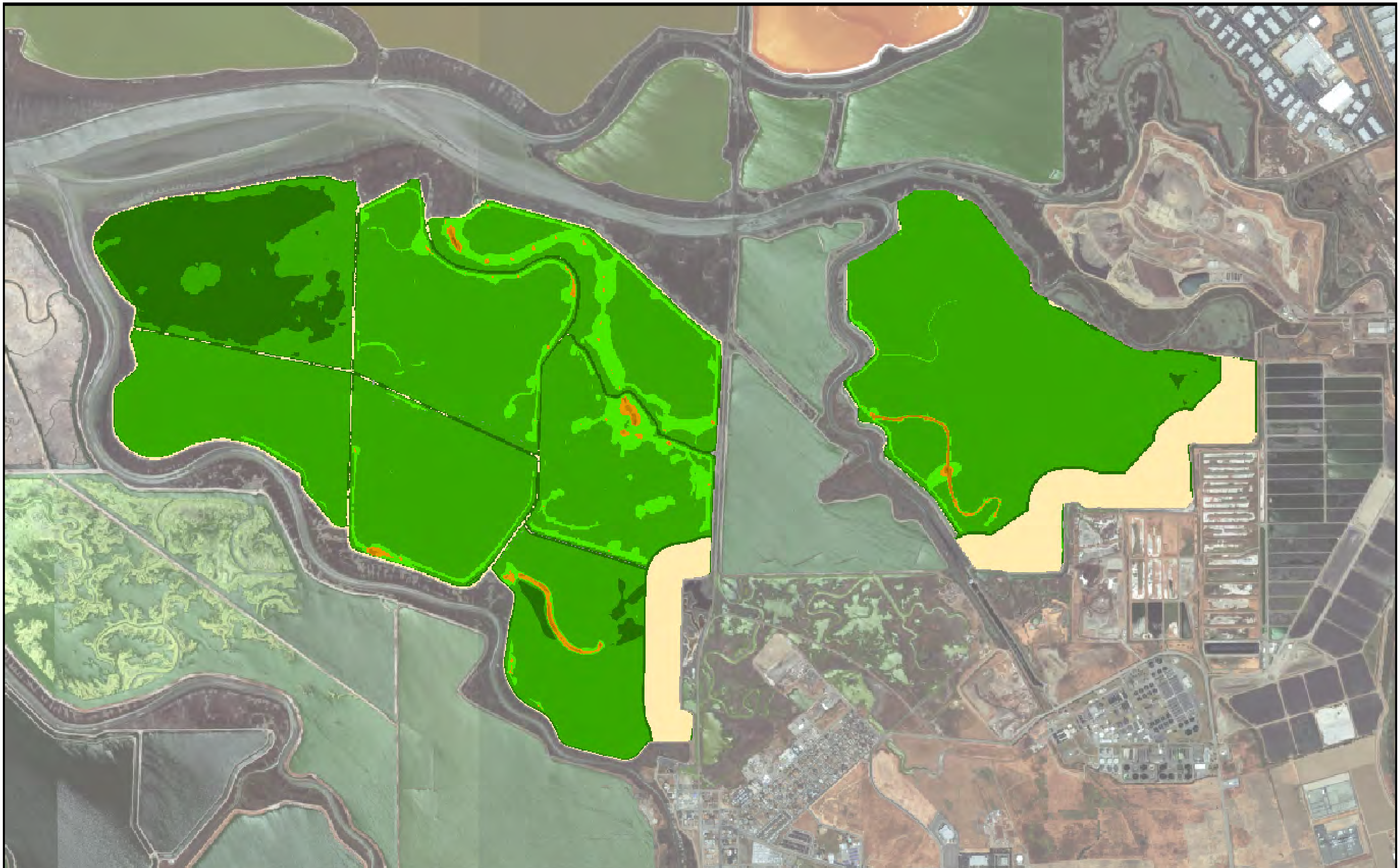

C0 = 200 mg/L, NRC-III, organics = 1 mm/yr
Start A12 in 2017, A9-11 in 2022, A18 in 2027,
and A13-15 in 2030. Fill 1:100

N

0 1,000 2,000 4,000 6,000 Feet

Deep Subtidal	Intertidal Mudflat high
Shallow Subtidal A	Cordgrass Dominated low
Shallow Subtidal B	Cordgrass Dominated high
Intertidal Mudflat low	Pickleweed Dominated
Intertidal Mudflat mid low	Upland
Intertidal Mudflat mid high	

figure 16

Shoreline Study Alternatives
2067 Marsh Elevations with Prelim
Alt 3 Transitional - Upland Fill Footprint

Proj. # 211259

ESA PWA

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